Resolving a nuclear disk and molecular outflows in the compact obscured nucleus IRAS 17578-0400

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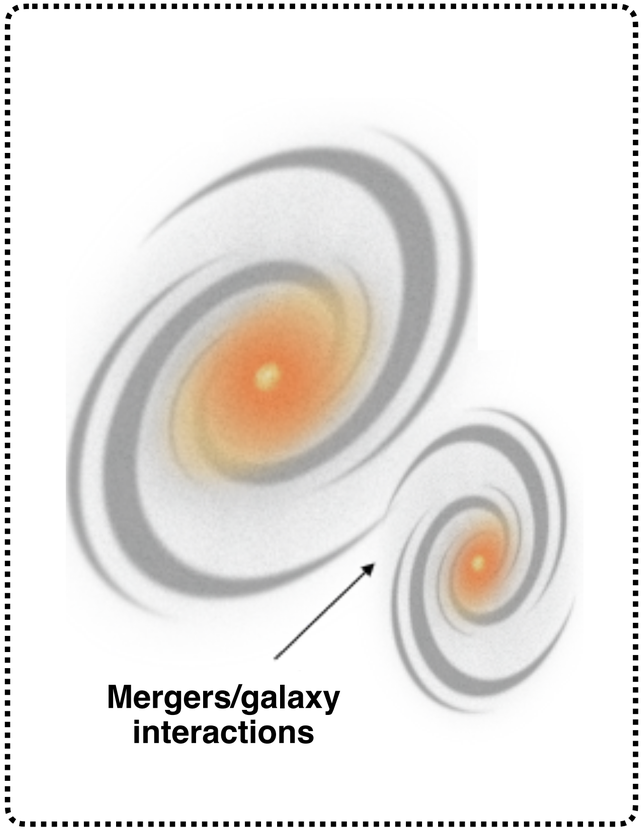
Image credits: NASA/JPL-Caltech

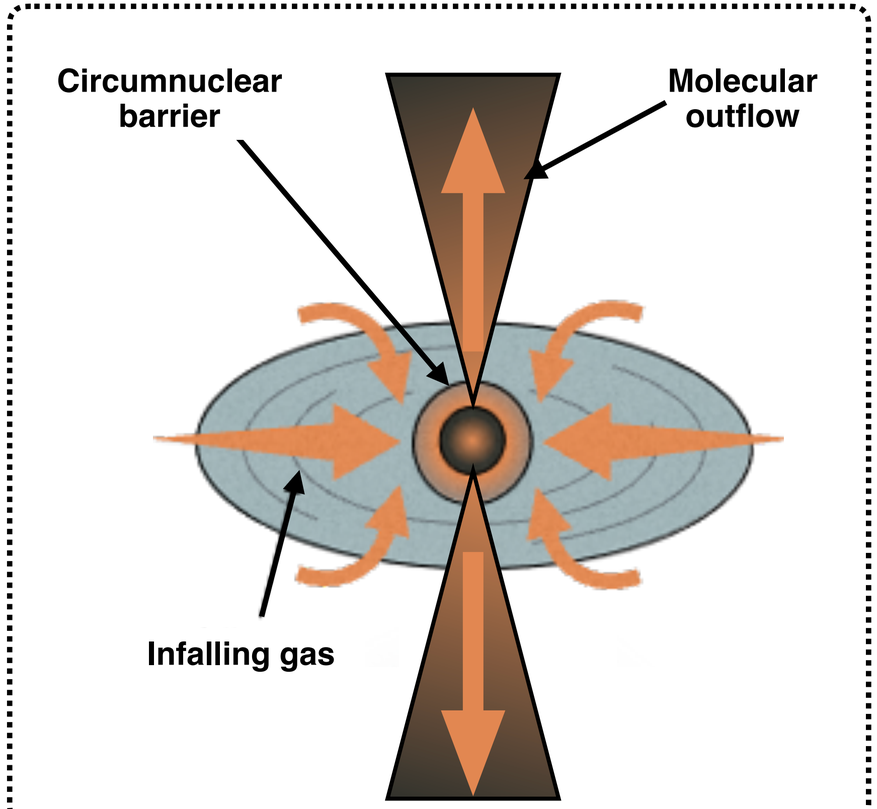
Compact Obscured Nuclei (CONs)

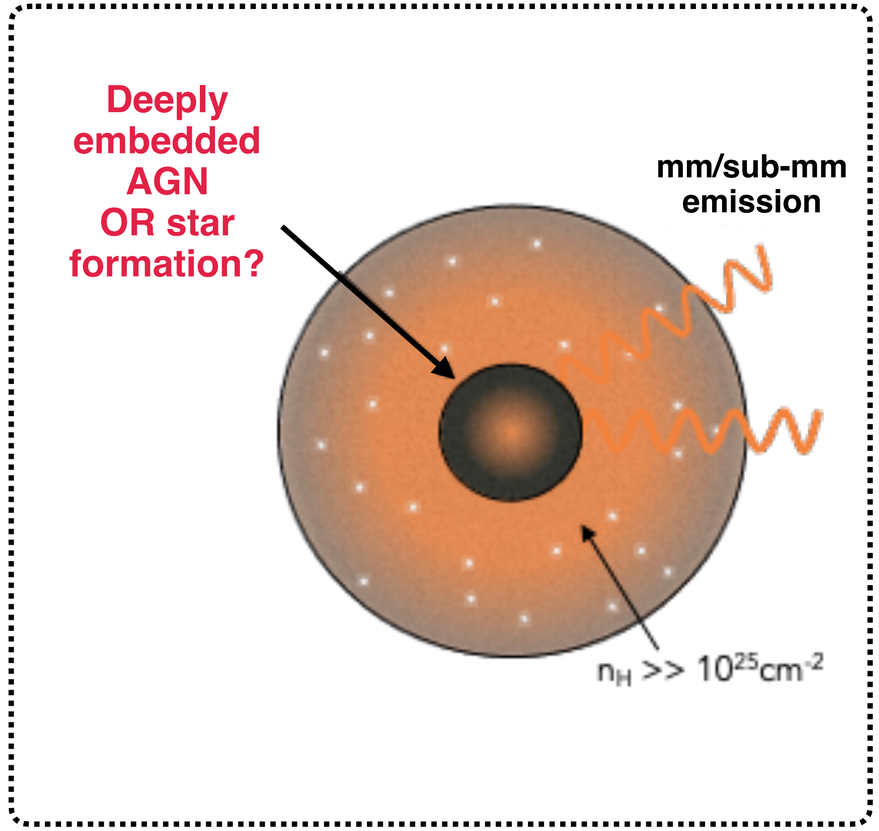
Extremely compact (r < 100 pc) nuclei in some (U)LIRGs

Aalto et al., 2015, 2018; Falstad et al. 2021; …

Intense IR emission from warm dust with column densities $n_{\rm H} \gg 10^{25}\,{\rm cm}^{-2}$ → **excitement of vibrational HCN J=3-2 transition** $\Sigma_{\rm HCN-vib} > 1\,L_\odot\,{\rm pc}^{-2}$







Credit: adapted images of Clare Wethers (private communication)

IRAS 17578-0400 & ALMA observations

Torbaniuk et al. 2026, in preparation

LIRG $z = 0.0134$ Falstad et al. 2021

RA: 18h 00m 31.99s. Dec: -04d 00m 55.00s

$L_{\mathrm{IR}} = 2.3 \times 10^{11} L_{\odot}$

$L_{\mathrm{FIR}} = 2.0 \times 10^{11} L_{\odot}$ Sanders et al. 2003

$\mathrm{SFR} = 38.1\, \mathrm{M}_{\odot}/\mathrm{year}$ Randriamanakoto et al. 2013

Inclination: ~81 degrees Makarov et al. 2014

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Band	Frequency (LSB/USB)	Angular resolution (natural/uniform)	
B3	95.47—98.97 GHz // 107.21—110.86 GHz	0.06–0.03 arcsec	17-9 pc
B5	165.95—169.77 GHz // 178.07—181.81 GHz	0.05–0.03 arcsec	14-9 pc
B6	246.63—250.66 GHz // 261.45—265.11 GHz	0.03–0.015 arcsec	9-4 pc
B7-321	302.50—305.85 GHz // 314.35—317.92 GHz	0.023–0.013 arcsec	7-4 pc
B7-325	306.25—309.80 GHz // 318.10—321.79 GHz	0.028–0.011 arcsec	8-3 pc

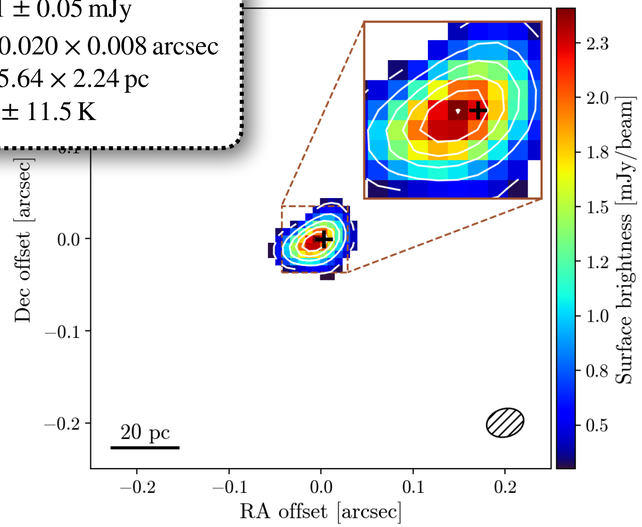
B3/B6: 2019.1.01612.S (PI: N. Falstad) **B5/B7-321/B7-325:** 2022.1.00738.S (PI: F. Stanley)

Continuum (uniform weighting)

Torbaniuk et al. 2026, in preparation

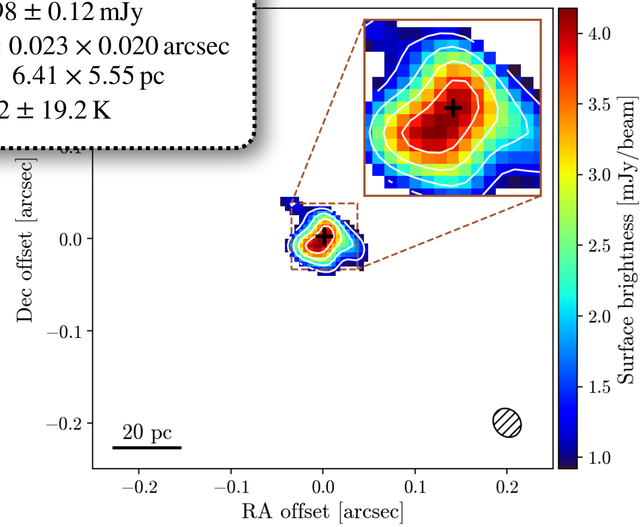
Band 3 (103 GHz)

$S_{\nu,\mathrm{peak}} = 2.41 \pm 0.13$ mJy/beam
$S_{\nu,\mathrm{int}} = 3.51 \pm 0.05$ mJy
FWHM $= 0.020 \times 0.008$ arcsec
5.64×2.24 pc
$T_\mathrm{B} = 222.1 \pm 11.5$ K



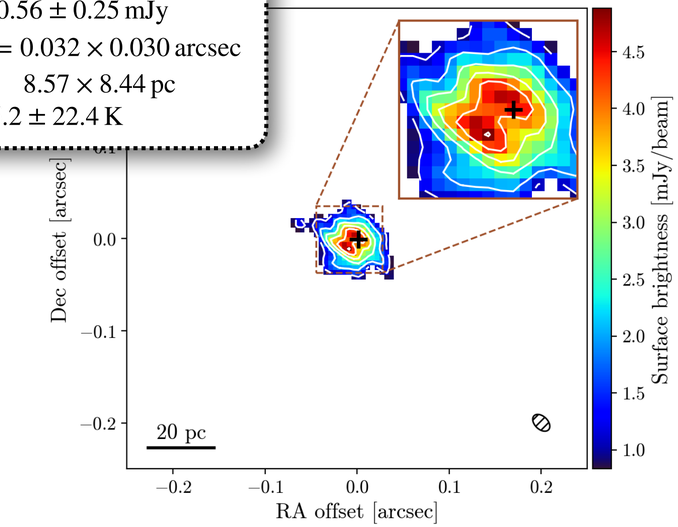
Band 5 (167 GHz)

$S_{\nu,\mathrm{peak}} = 4.18 \pm 0.41$ mJy/beam
$S_{\nu,\mathrm{int}} = 8.98 \pm 0.12$ mJy
FWHM $= 0.023 \times 0.020$ arcsec
6.41×5.55 pc
$T_\mathrm{B} = 195.2 \pm 19.2$ K



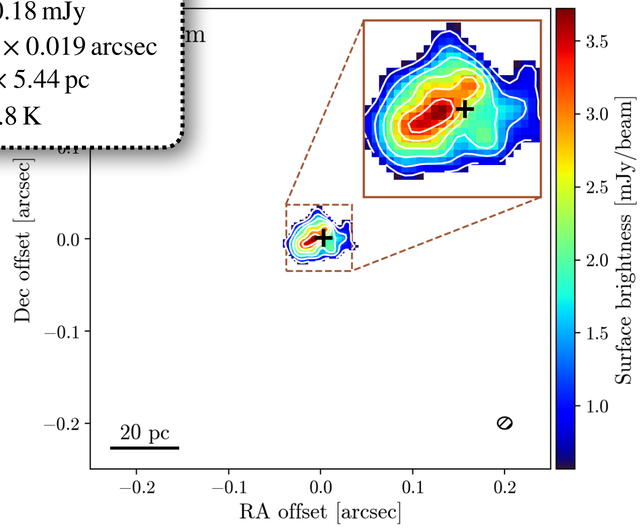
Band 6 (256 GHz)

$S_{\nu,\mathrm{peak}} = 4.88 \pm 0.37$ mJy/beam
$S_{\nu,\mathrm{int}} = 30.56 \pm 0.25$ mJy
FWHM $= 0.032 \times 0.030$ arcsec
8.57×8.44 pc
$T_\mathrm{B} = 295.2 \pm 22.4$ K



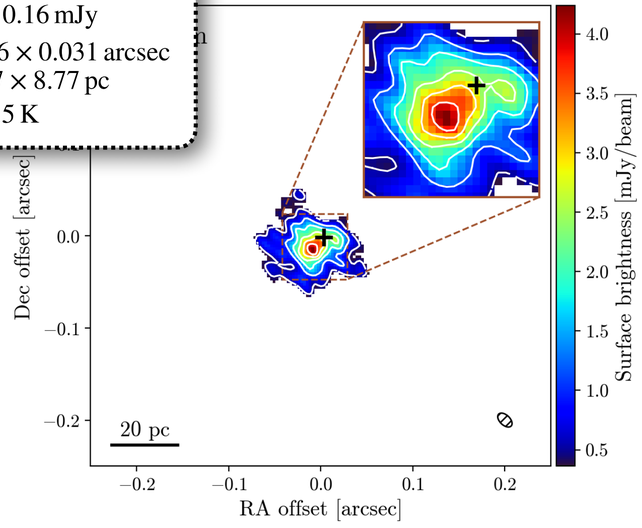
Band 7-321 (310 GHz)

$S_{\nu,\mathrm{peak}} = 3.72 \pm 0.25$ mJy/beam
$S_{\nu,\mathrm{int}} = 22.34 \pm 0.18$ mJy
FWHM $= 0.030 \times 0.019$ arcsec
8.44×5.44 pc
$T_\mathrm{B} = 238.4 \pm 15.8$ K



Band 7-325 (314 GHz)

$S_{\nu,\mathrm{peak}} = 4.24 \pm 0.16$ mJy/beam
$S_{\nu,\mathrm{int}} = 35.46 \pm 0.16$ mJy
FWHM $= 0.036 \times 0.031$ arcsec
10.07×8.77 pc
$T_\mathrm{B} = 254.1 \pm 9.5$ K



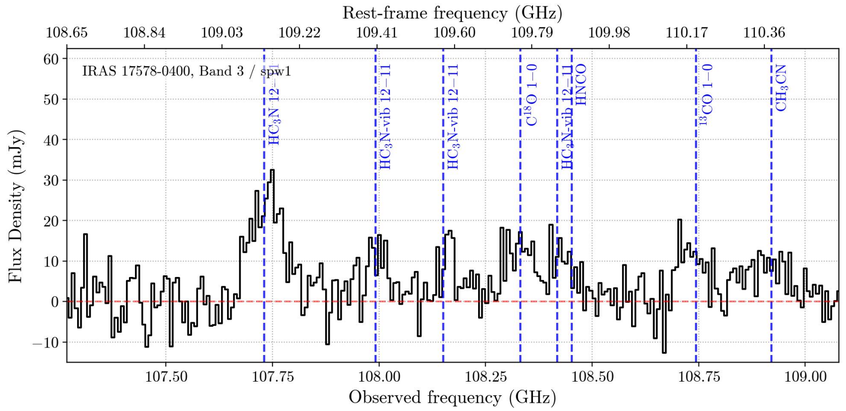
Emission lines (Band 3 & 6)

Torbaniuk et al. 2026, in preparation

Band 3:

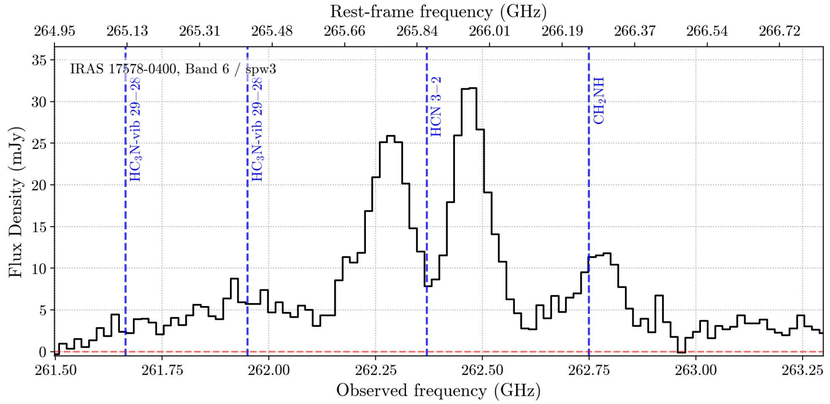
CS 2–1	97.98 GHz
HC_3N v=0 11–10	100.08 GHz
HC_3N v=0 12–11	109.17 GHz
HC_3N v_6=1 12–11	109.44 GHz
HC_3N v_7=1 12–11	109.60 GHz

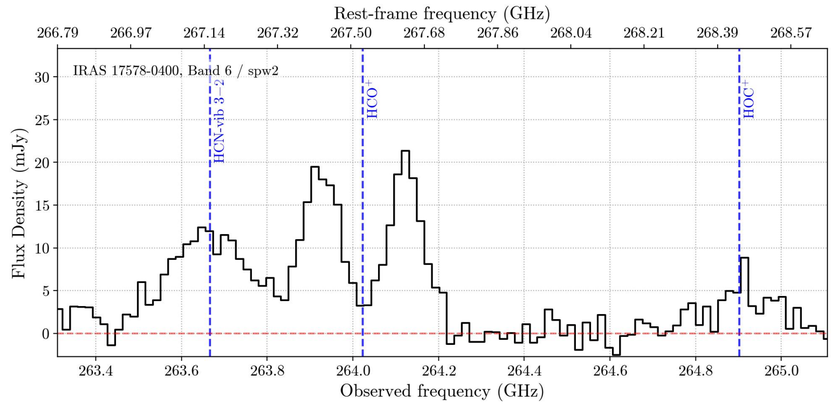
$C^{18}O$ 1–0	109.78 GHz
HC_3N v_7=2 12–11	109.87 GHz
HNCO $5_{0,5}$–$4_{0,4}$	109.91 GHz
^{13}CO 1–0	110.20 GHz
CH_3CN 6_0–5_0 to 6_5–5_5	~110.38 GHz



Band 6:

HCN v_2=1f 3–2	267.20 GHz
HCO^+ 3–2	267.56 GHz
HCN v=0 3–2	265.89 GHz
HC_3N v_6=1,v_7=1 29–28	265.17 GHz
HC_3N v_7=2 29–28	265.46 GHz
CH_2NH $4_{1,3}$–$3_{1,2}$	266.27 GHz
CH_2NH $6_{0,6}$–$5_{1,5}$	251.42 GHz
SO v=0 5_6-4_5	251.83 GHz
…	





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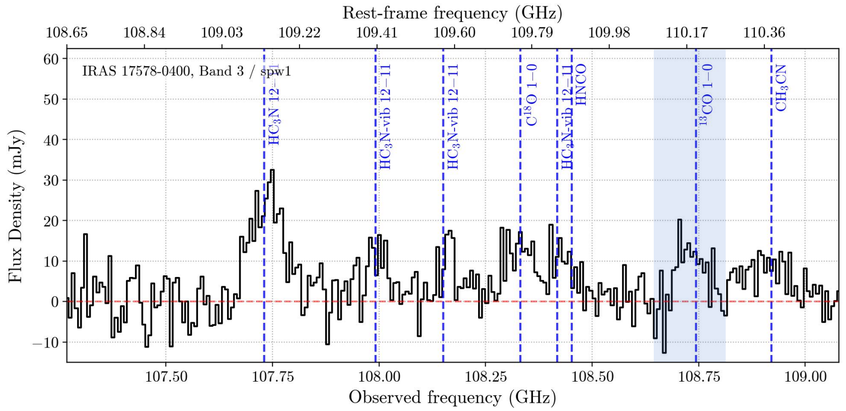
CH_3CN 6_0–5_0 to 6_5–5_5	~110.38 GHz



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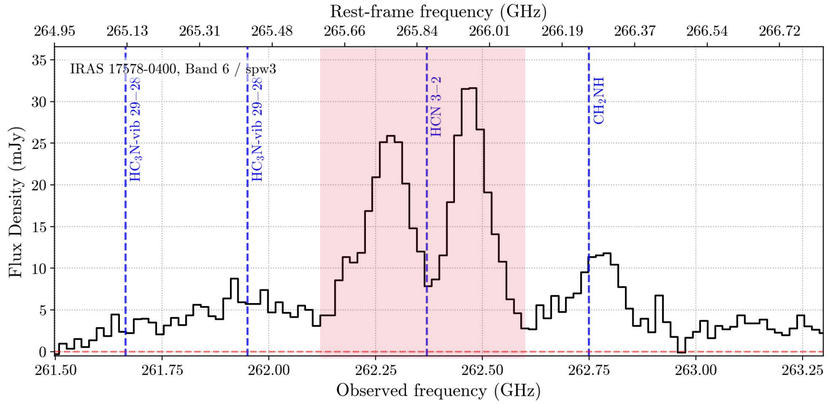

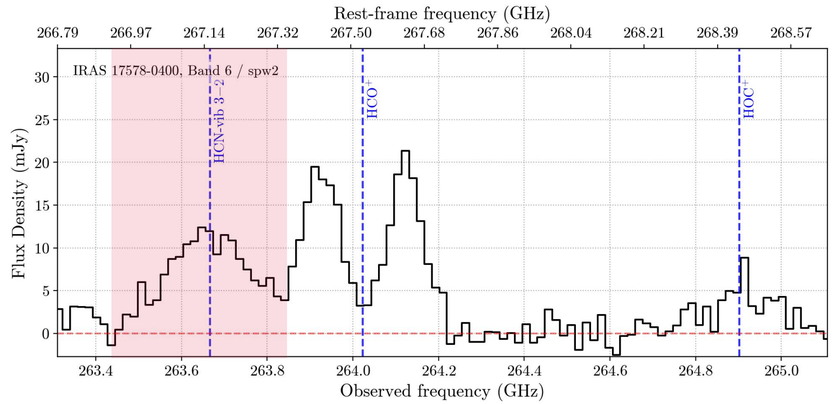

Emission lines & Moment maps

Tracers of...

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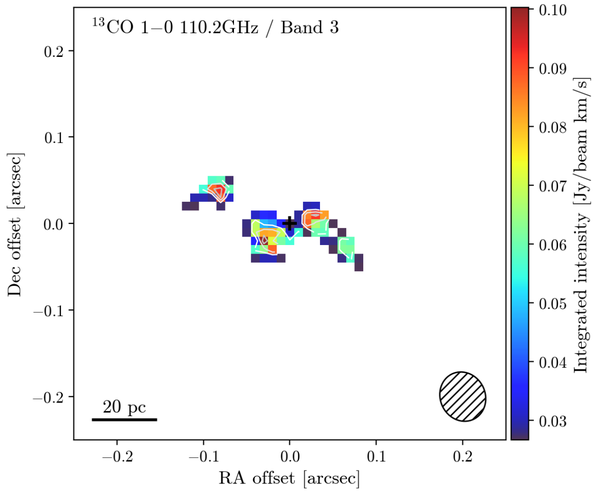
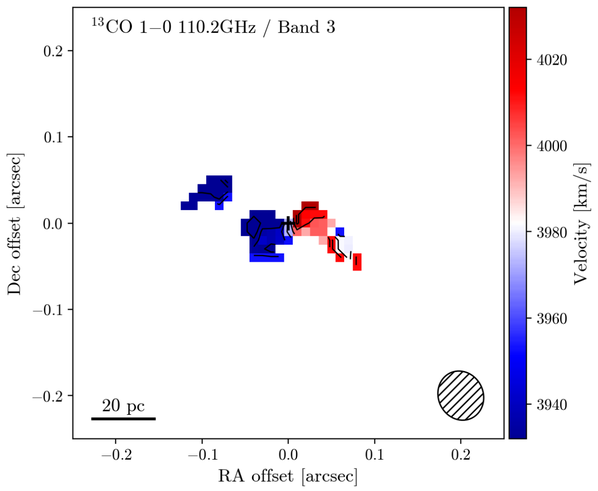
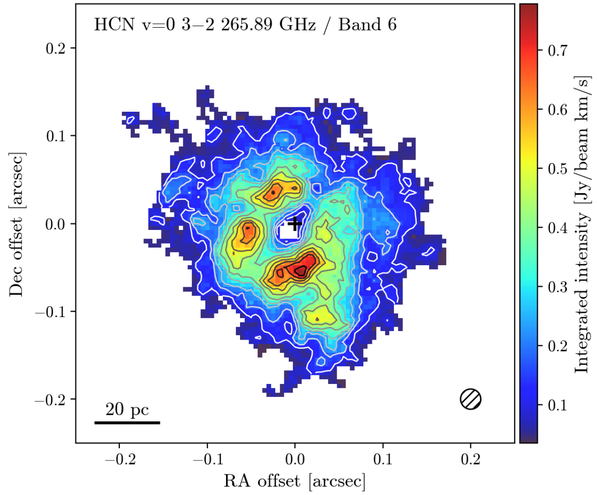
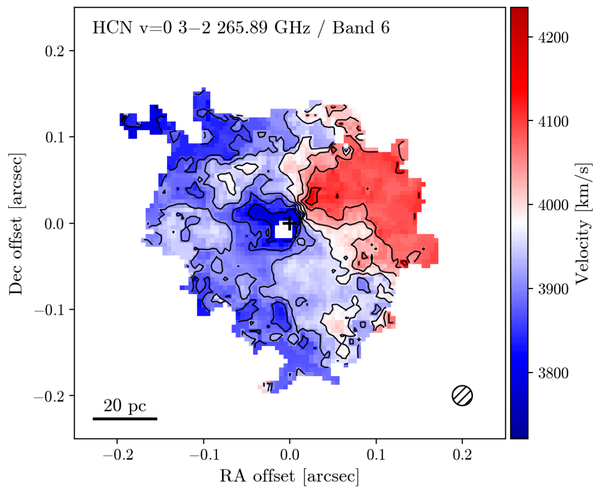
'total' molecular gas



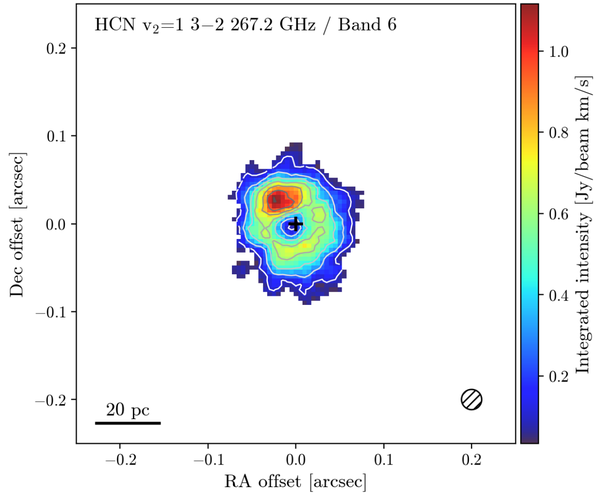


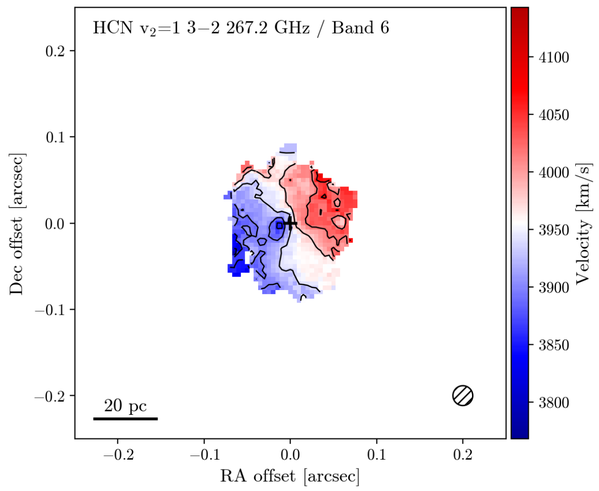
dense molecular gas





very dense, hot molecular gas





^{13}CO

$S_{\nu,\mathrm{peak}} = 0.10 \pm 0.02\,\mathrm{Jy/beam \cdot km/s}$

$S_{\nu,\mathrm{int}} = 0.11 \pm 0.02\,\mathrm{Jy \cdot km/s}$

$\mathrm{FWHM} = 0.057'' = 16.30\,\mathrm{pc}$

$L'_{^{13}\mathrm{CO}} = 9.1 \cdot 10^5\,\mathrm{K\,km/s\,pc^2} = 40\,L_\odot$

HCN

$S_{\nu,\mathrm{peak}} = 0.78 \pm 0.02\,\mathrm{Jy/beam \cdot km/s}$

$S_{\nu,\mathrm{int}} = 27.46 \pm 0.10\,\mathrm{Jy \cdot km/s}$

$\mathrm{FWHM} = 0.178'' \times 0.139'' = 50.97 \times 39.73\,\mathrm{pc}$

$L'_{\mathrm{HCN}} = 4.2 \cdot 10^7\,\mathrm{K\,km/s\,pc^2} = 2.5 \cdot 10^4\,L_\odot$

HCN-vib

$S_{\nu,\mathrm{peak}} = 1.12 \pm 0.03\,\mathrm{Jy/beam \cdot km/s}$

$S_{\nu,\mathrm{int}} = 11.25 \pm 0.12\,\mathrm{Jy \cdot km/s}$

$\mathrm{FWHM} = 0.095'' \times 0.080'' = 27.03 \times 22.85\,\mathrm{pc}$

$L'_{\mathrm{HCN-vib}} = 1.7 \cdot 10^7\,\mathrm{K\,km/s\,pc^2} = 1.1 \cdot 10^4\,L_\odot$

Multi-tracer view of the nuclear disk

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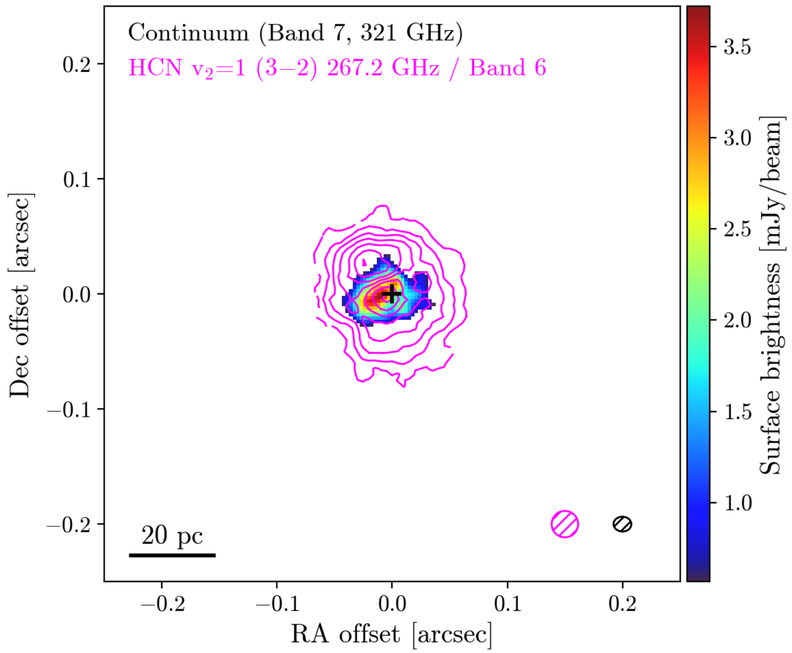
Band 7 / 321 GHz continuum
HCN-vib moment 0



Band 7 / 321 GHz continuum
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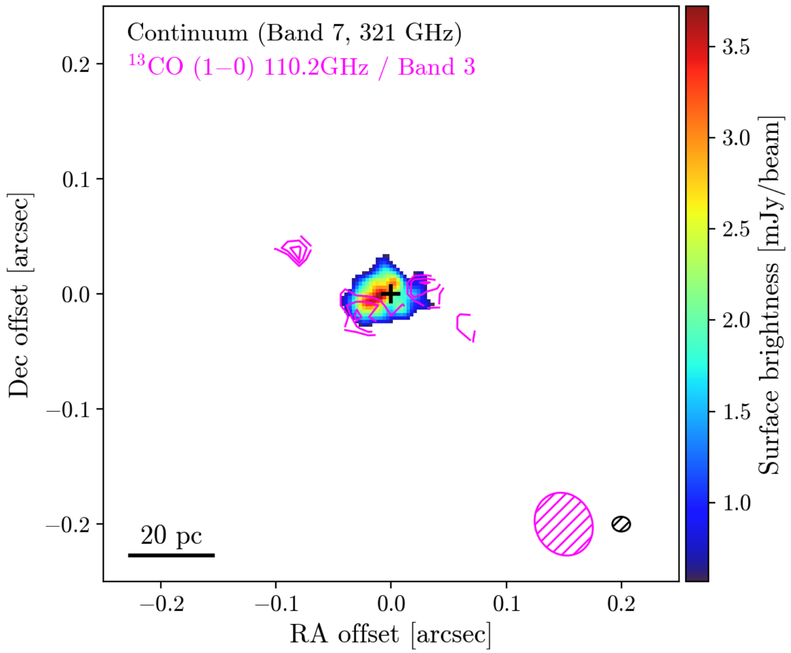
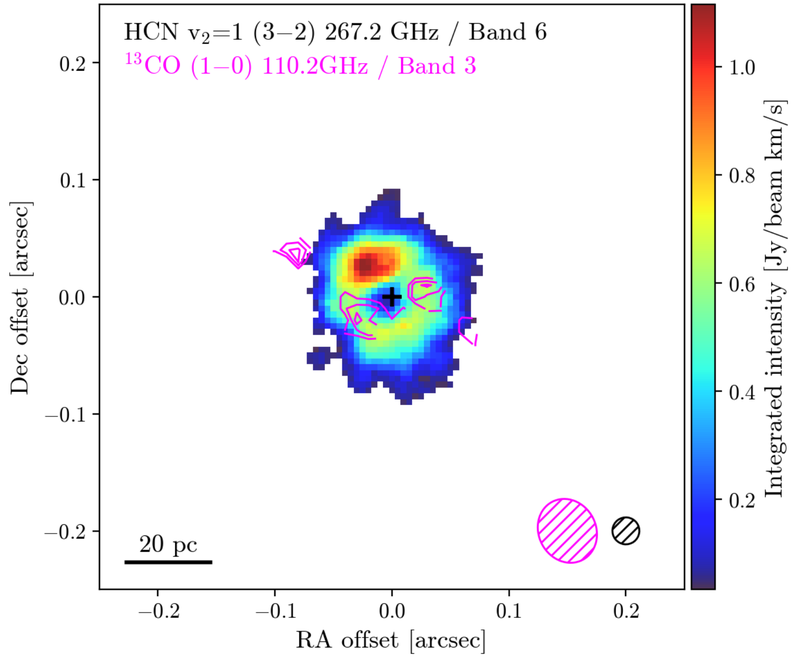


HCN-vib moment 0
^{13}CO moment 0



Kinematics, PV diagrams & M_{BH}

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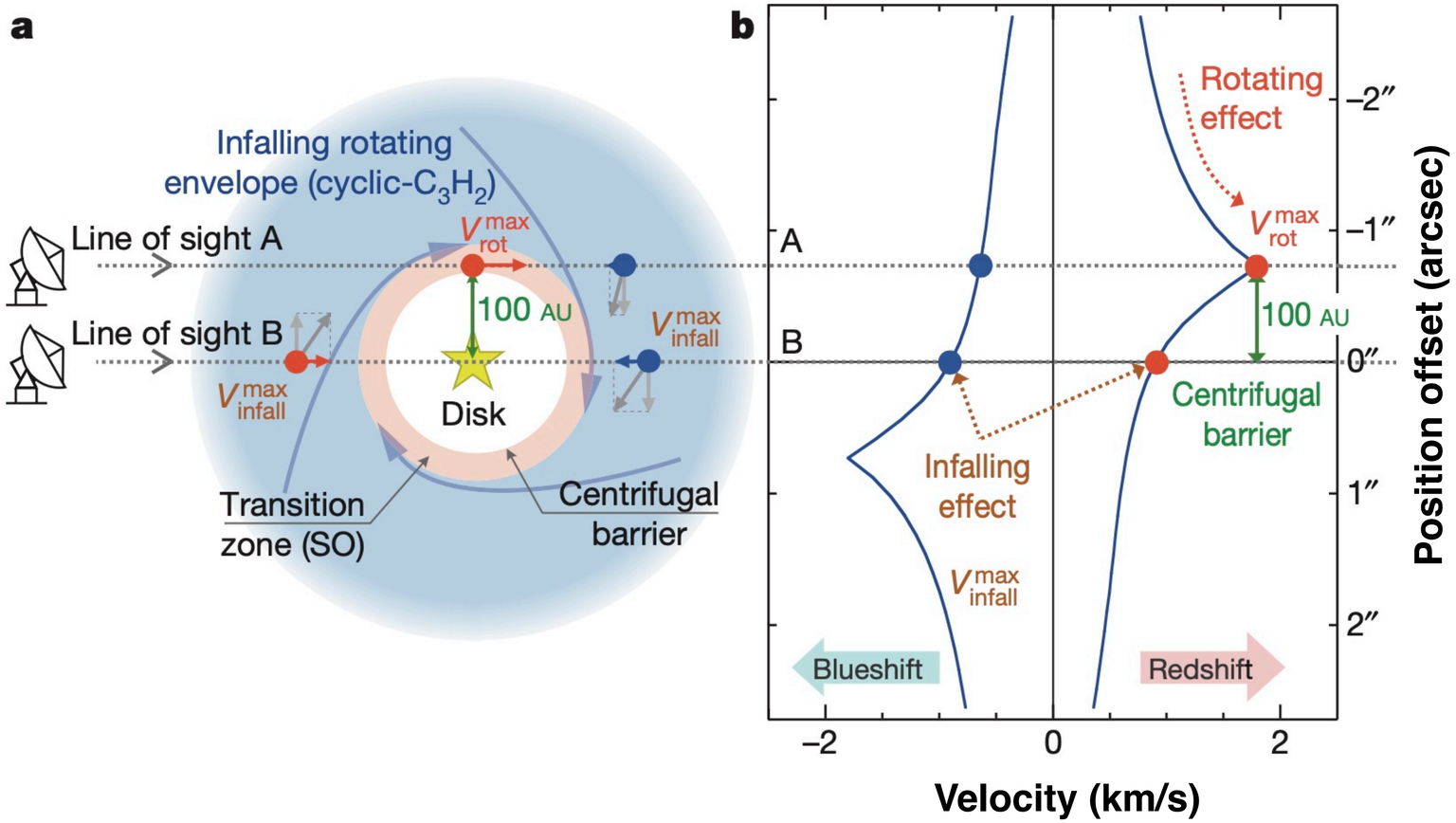
Position-velocity (PV) diagrams:

adopting the model from **Sakai+ 2014, Nature, 207**
used for the protostar disk studies (outflows not taken into account)



Radial (infall) velocity:

$$v_r = \sqrt{\frac{2GM}{r} - \left(\frac{L}{m}\right)^2 \frac{1}{r^2}}$$

Rotation velocity:

$$v_\theta = \left(\frac{L}{m}\right)\frac{1}{r}$$

Keplerian rotating disk velocity:

$$v_{\mathrm{Kepl}} = \sqrt{\frac{GM}{r}}$$

where G — the gravitation constant, M — the central enclosed mass, L — the angular momentum, m — the particle in a motion, r — the radius

PRELIMINARY

Kinematics, PV diagrams & M_{BH}

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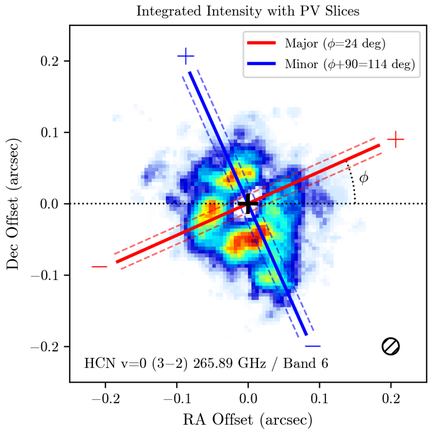
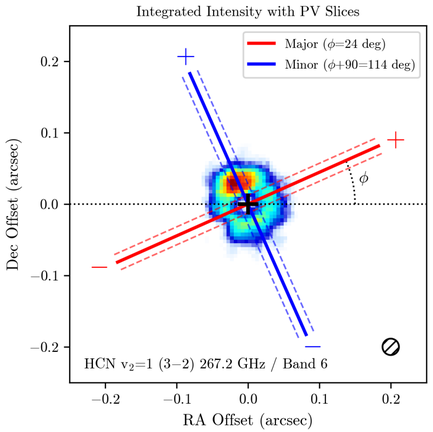
Major axis PV:

HCN 3-2

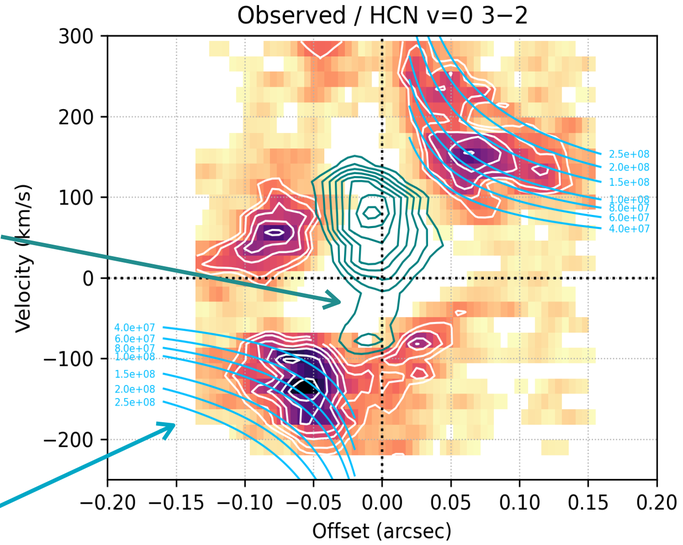


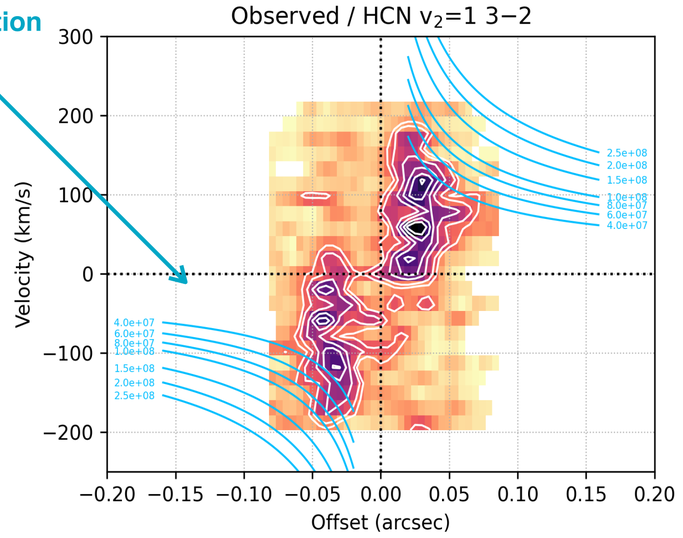
HCN-vib

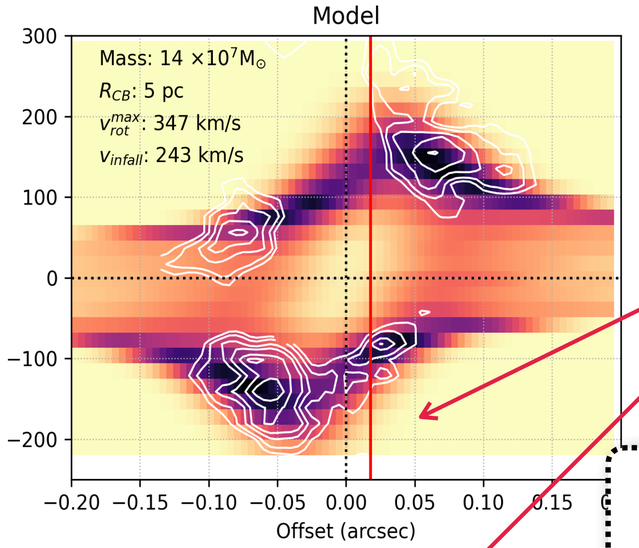


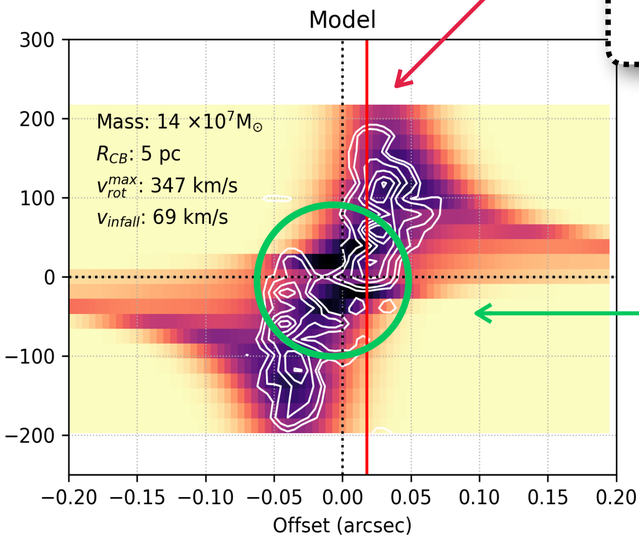
Foreground gas of the torus (LOS) with rotation around ~100 km/s

Mass assuming Keplerian disk rotation









Centrifugal barrier: outer radius of the torus?

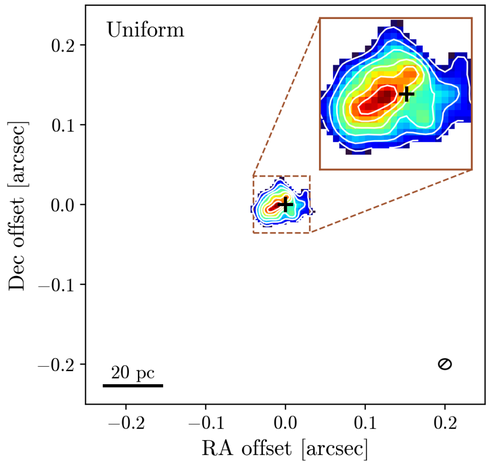
Enclosed mass:

$$M_{encl} = 1.4 \cdot 10^8 M_\odot$$

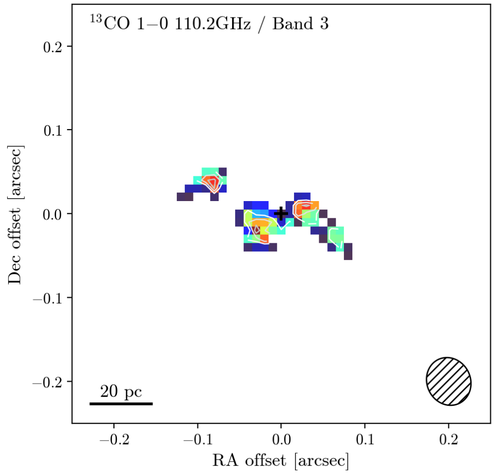
Possible outflow base?

Inner pc-scale structure

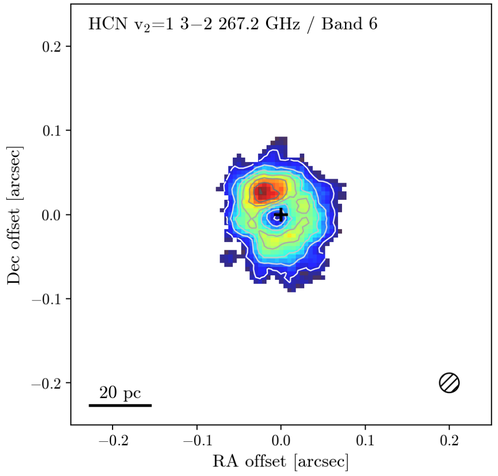
Disk-like continuum morphology (~8 pc)



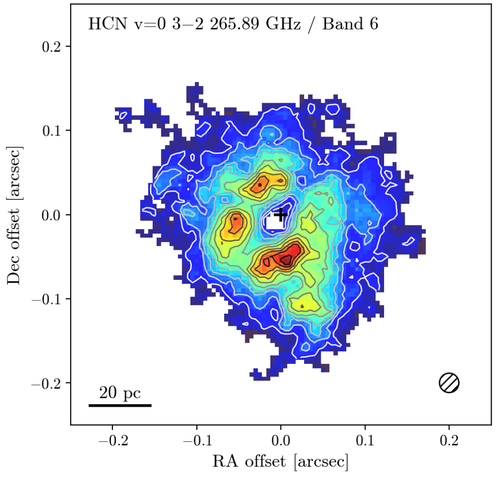
^{13}CO extended disk (~16 pc)



Inner (20 pc) HCN-vib disk + infalling gas (~69 km/s) + possible outflow launching site

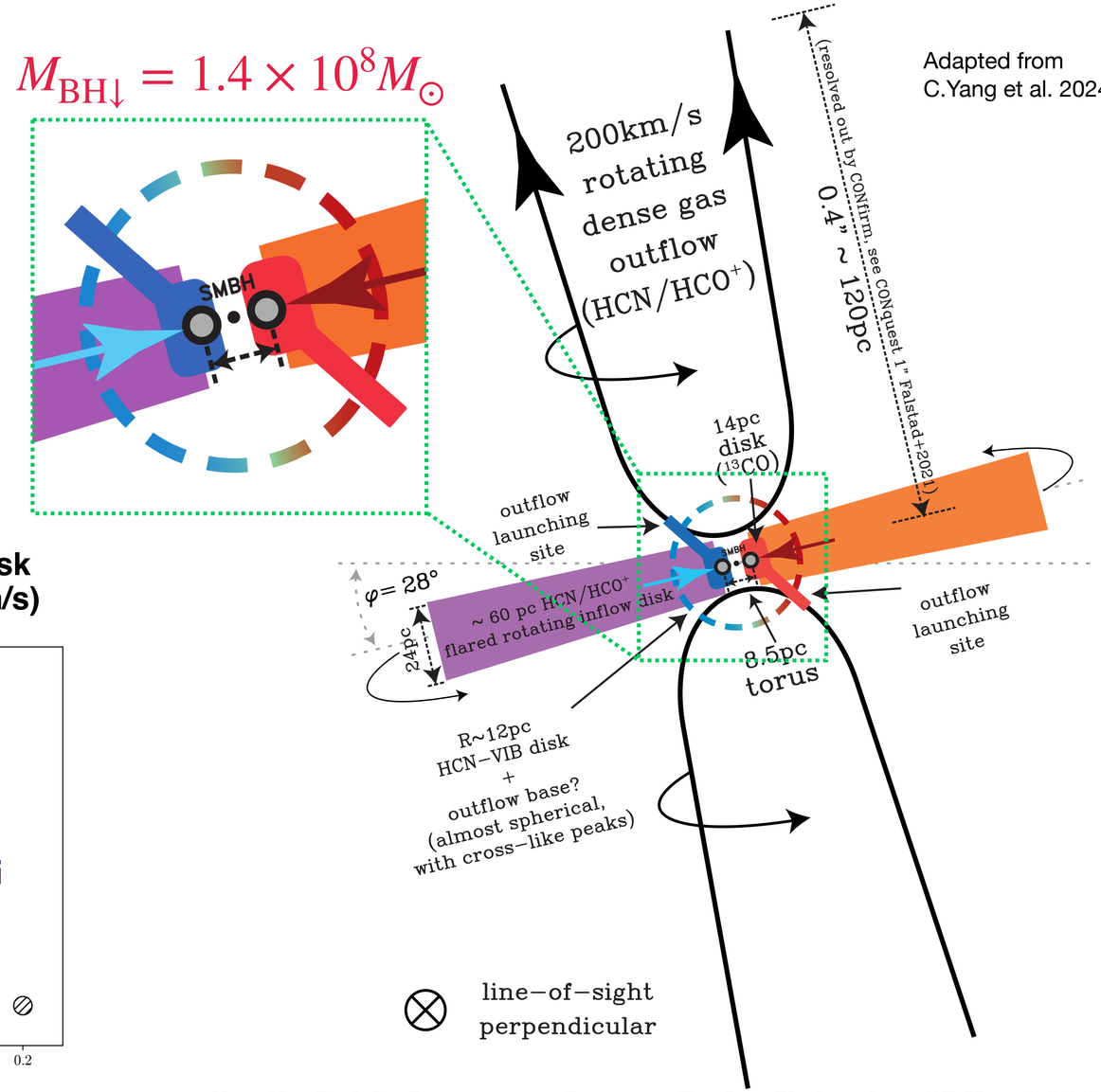


60 pc HCN rotating disk + infalling gas (243 km/s)



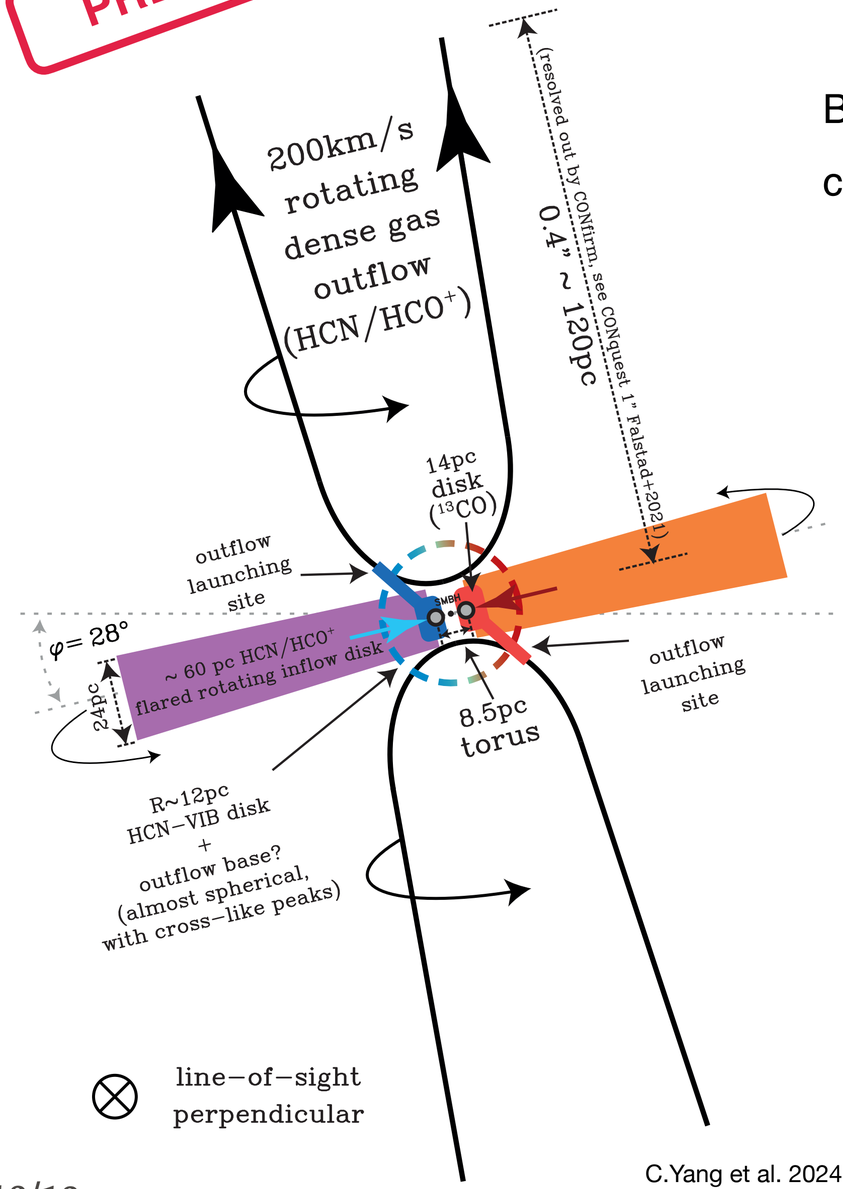
Torbaniuk et al. 2026, in preparation

Adapted from C.Yang et al. 2024



Conclusions

PRELIMINARY



C.Yang et al. 2024

Torbaniuk et al. 2026, in preparation

Based on multi-band continuum and lines data from ALMA, we found that compact obscured nucleus **IRAS17578-0400** shows the present of:

1) Compact dust continuum (~8 pc) resolved at Band 7 / 321 GHz with **disk/torus** morphology with $T_B \gtrsim 200\,\mathrm{K}$;

2) **^{13}CO** emission traces **extended rotating disk** (~16 pc) with signs of outflow;

3) **HCN-vib** emission confined to inner ~20 pc → dense nuclear gas, strong AGN indicator, possible **outflow launching site + weak infall component (69 km/s)**

4) “Outer" 60 pc **HCN** rotating (~350 km/s) inflowing disk (reaching ~243 km/s infall velocity)

5) Enclosed mass estimates (**upper limit on M_{BH})**: around $1.4 \cdot 10^8 M_\odot$ within 10 pc area based on dense gas tracers (HCN/HCN-vib)

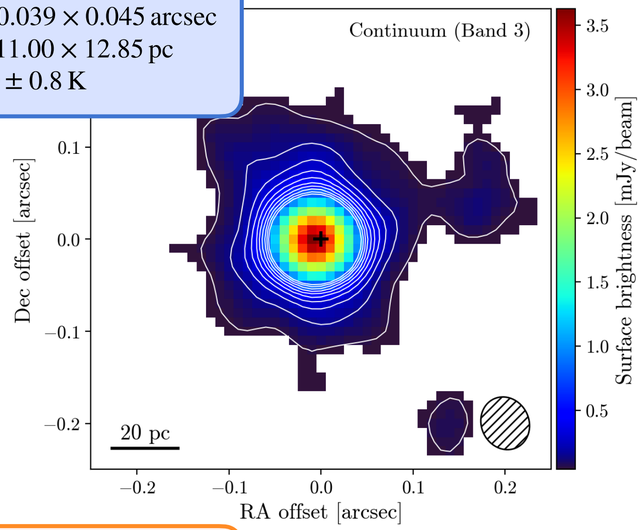
Thank you for your attention!

Additional slides:

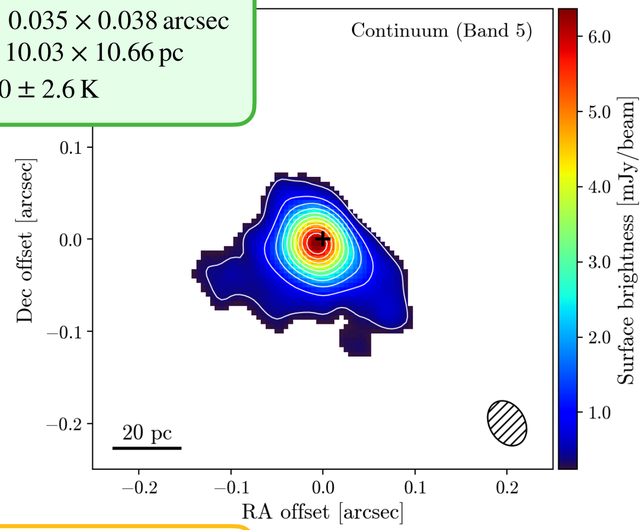
Continuum (natural weighting)

Torbaniuk et al. 2026, in preparation

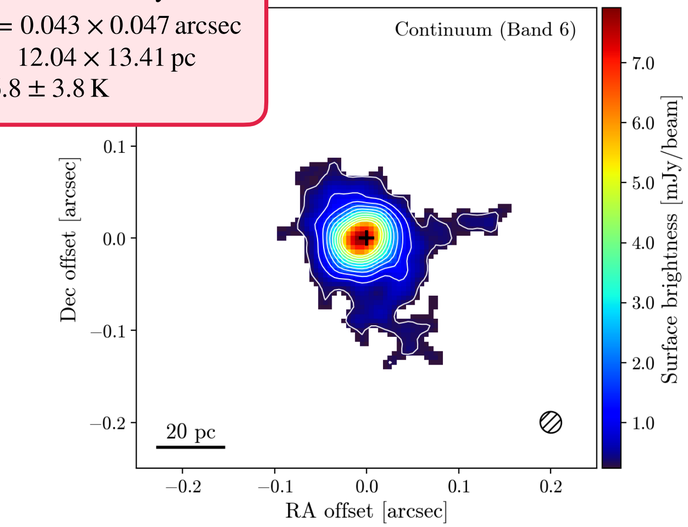
$S_{\nu,\mathrm{peak}} = 3.63 \pm 0.02$ mJy/beam
$S_{\nu,\mathrm{int}} = 6.84 \pm 0.01$ mJy
FWHM $= 0.039 \times 0.045$ arcsec
11.00×12.85 pc
$T_\mathrm{B} = 138.0 \pm 0.8$ K



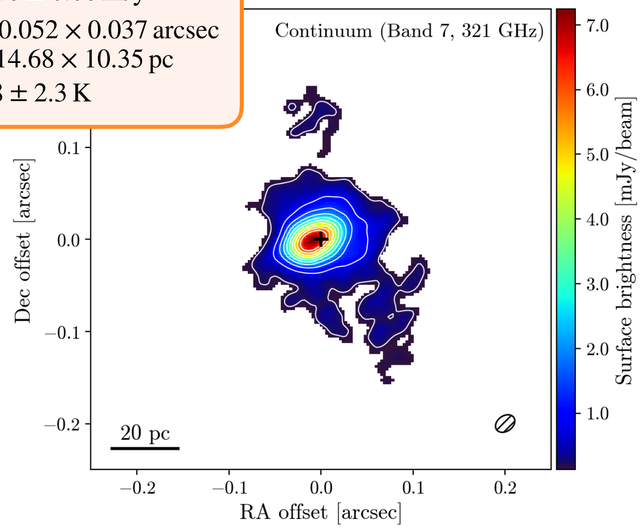
$S_{\nu,\mathrm{peak}} = 6.36 \pm 0.12$ mJy/beam
$S_{\nu,\mathrm{int}} = 13.80 \pm 0.04$ mJy
FWHM $= 0.035 \times 0.038$ arcsec
10.03×10.66 pc
$T_\mathrm{B} = 140.0 \pm 2.6$ K



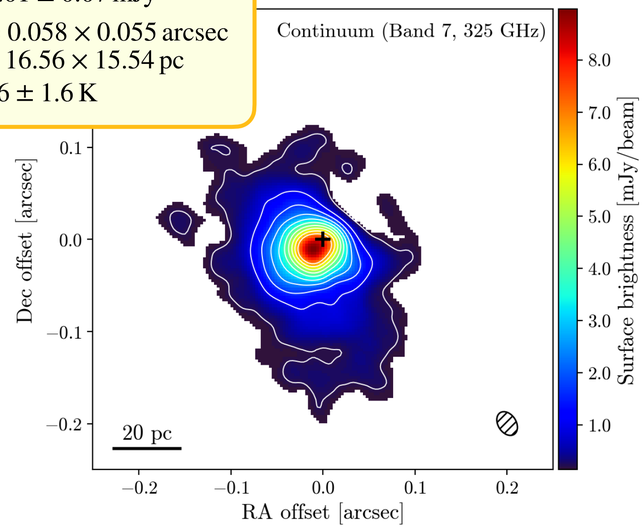
$S_{\nu,\mathrm{peak}} = 7.91 \pm 0.11$ mJy/beam
$S_{\nu,\mathrm{int}} = 47.02 \pm 0.12$ mJy
FWHM $= 0.043 \times 0.047$ arcsec
12.04×13.41 pc
$T_\mathrm{B} = 276.8 \pm 3.8$ K



$S_{\nu,\mathrm{peak}} = 7.24 \pm 0.07$ mJy/beam
$S_{\nu,\mathrm{int}} = 49.26 \pm 0.06$ mJy
FWHM $= 0.052 \times 0.037$ arcsec
14.68×10.35 pc
$T_\mathrm{B} = 240.8 \pm 2.3$ K



$S_{\nu,\mathrm{peak}} = 8.97 \pm 0.07$ mJy/beam
$S_{\nu,\mathrm{int}} = 72.01 \pm 0.07$ mJy
FWHM $= 0.058 \times 0.055$ arcsec
16.56×15.54 pc
$T_\mathrm{B} = 202.6 \pm 1.6$ K



Continuum (uniform weighting)

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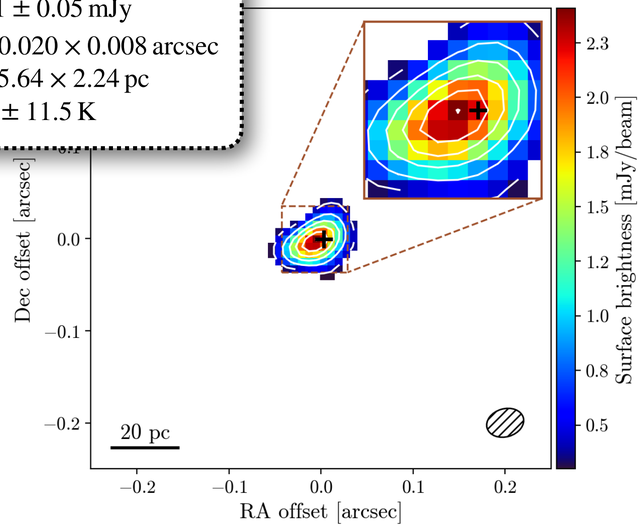
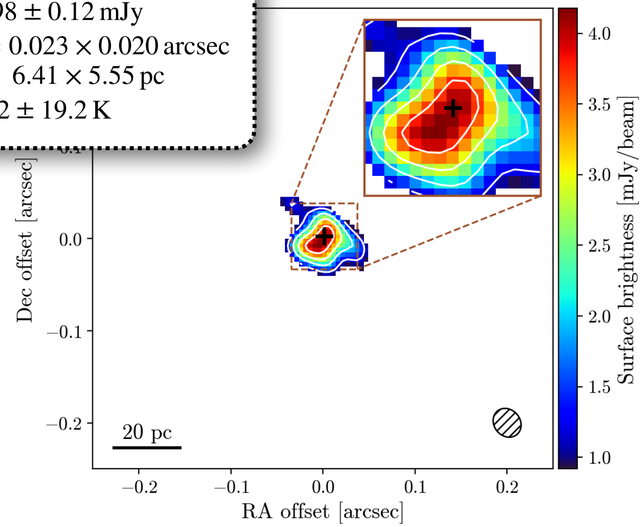
Band 3 (103 GHz)

$S_{\nu,\mathrm{peak}} = 2.41 \pm 0.13$ mJy/beam
$S_{\nu,\mathrm{int}} = 3.51 \pm 0.05$ mJy
FWHM $= 0.020 \times 0.008$ arcsec
5.64×2.24 pc
$T_\mathrm{B} = 222.1 \pm 11.5$ K



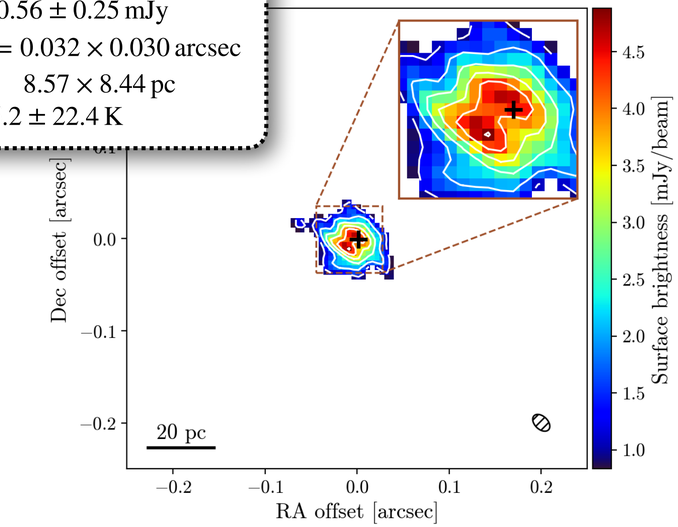
Band 5 (167 GHz)

$S_{\nu,\mathrm{peak}} = 4.18 \pm 0.41$ mJy/beam
$S_{\nu,\mathrm{int}} = 8.98 \pm 0.12$ mJy
FWHM $= 0.023 \times 0.020$ arcsec
6.41×5.55 pc
$T_\mathrm{B} = 195.2 \pm 19.2$ K



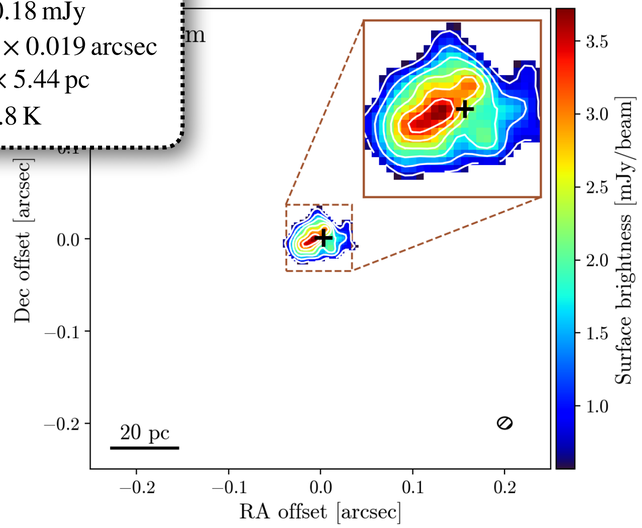
Band 6 (256 GHz)

$S_{\nu,\mathrm{peak}} = 4.88 \pm 0.37$ mJy/beam
$S_{\nu,\mathrm{int}} = 30.56 \pm 0.25$ mJy
FWHM $= 0.032 \times 0.030$ arcsec
8.57×8.44 pc
$T_\mathrm{B} = 295.2 \pm 22.4$ K



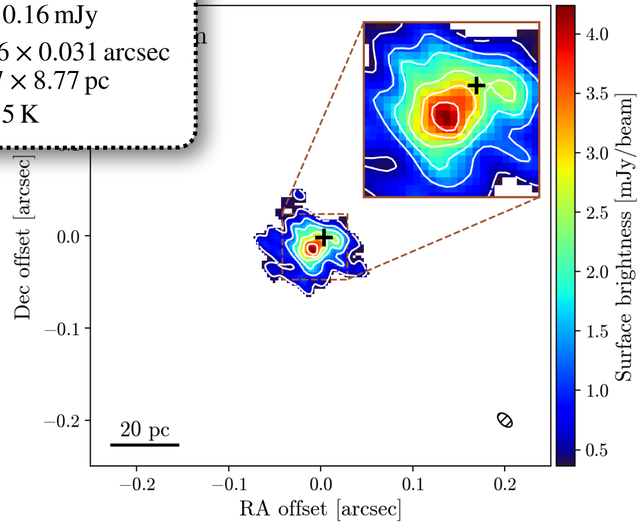
Band 7-321 (310 GHz)

$S_{\nu,\mathrm{peak}} = 3.72 \pm 0.25$ mJy/beam
$S_{\nu,\mathrm{int}} = 22.34 \pm 0.18$ mJy
FWHM $= 0.030 \times 0.019$ arcsec
8.44×5.44 pc
$T_\mathrm{B} = 238.4 \pm 15.8$ K



Band 7-325 (314 GHz)

$S_{\nu,\mathrm{peak}} = 4.24 \pm 0.16$ mJy/beam
$S_{\nu,\mathrm{int}} = 35.46 \pm 0.16$ mJy
FWHM $= 0.036 \times 0.031$ arcsec
10.07×8.77 pc
$T_\mathrm{B} = 254.1 \pm 9.5$ K



Spectral index

PRELIMINARY

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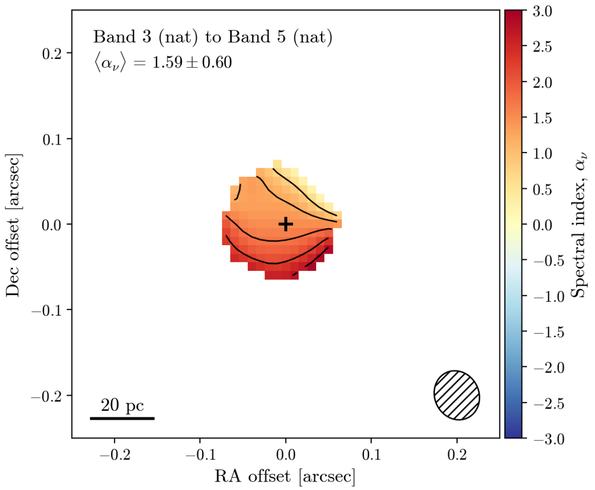
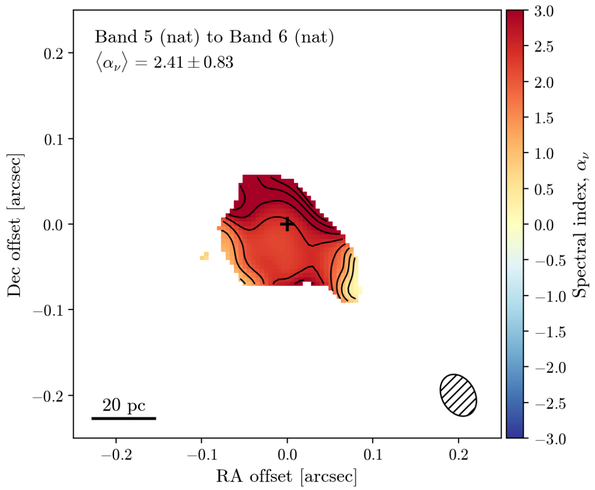
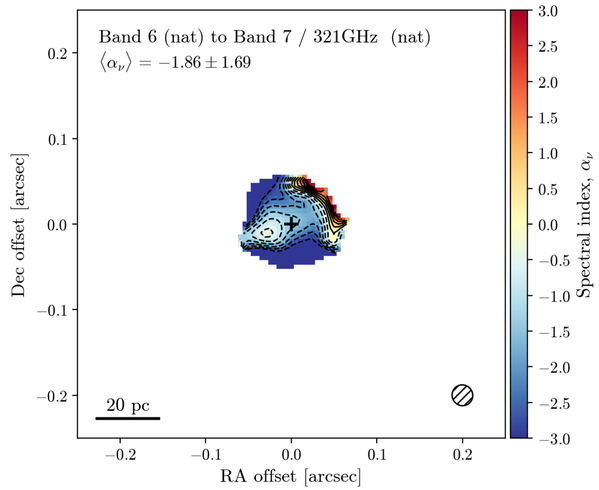
... increasing frequency

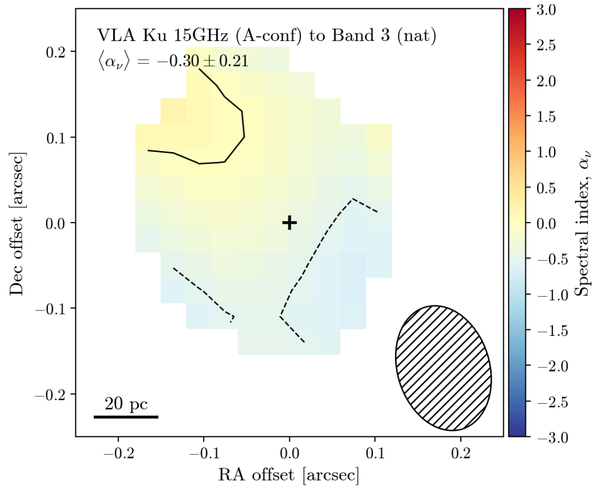
Thermal dust emission

SED flattening or turnover: optically thick dust / AGN torus/mm corona?

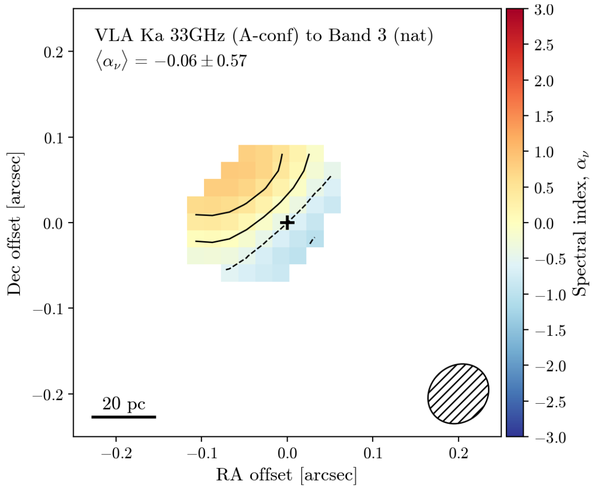




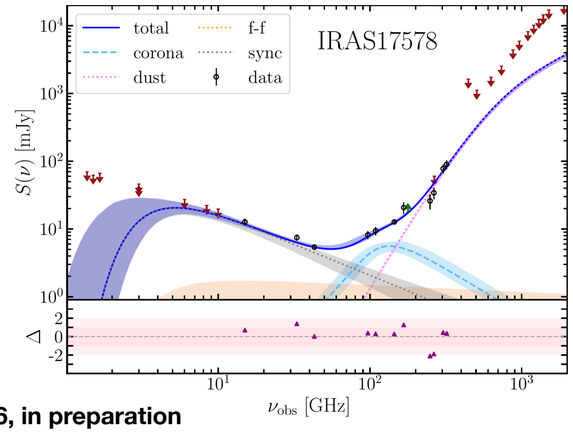




Steep synchrotron emission:
SN remnants or weak AGN jet?



free-free emission from stars



del Palacio et al. 2026, in preparation

ALMA & VLA continuum

Preliminary results

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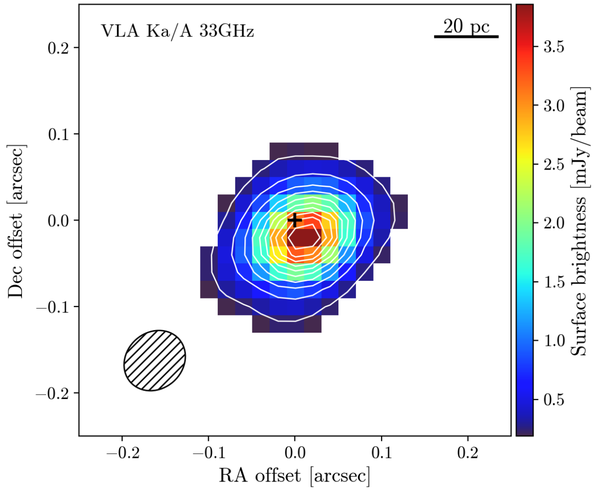
Ku band 33 GHz

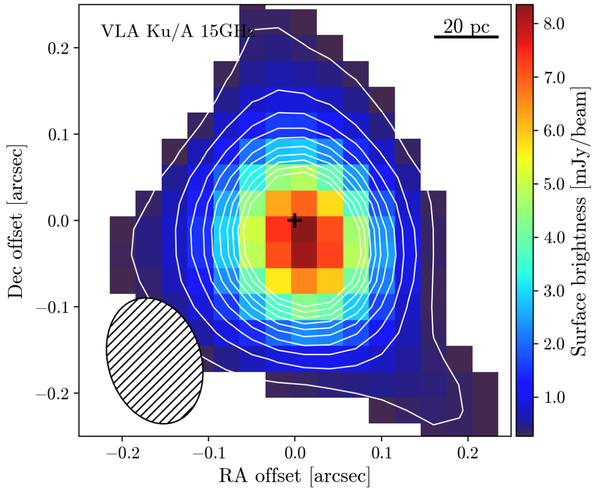
$S_{\nu,\mathrm{peak}} = 3.86 \pm 0.02$ mJy/beam
$S_{\nu,\mathrm{int}} = 6.52 \pm 0.01$ mJy
FWHM $= 0.065 \times 0.043$ arcsec
18.54×12.09 pc
$T_\mathrm{B} = 883.4 \pm 4.5$ K

Ka band 15 GHz

$S_{\nu,\mathrm{peak}} = 8.35 \pm 0.02$ mJy/beam
$S_{\nu,\mathrm{int}} = 12.89 \pm 0.01$ mJy
FWHM $= 0.071 \times 0.094$ arcsec
20.05×26.50 pc
$T_\mathrm{B} = 2832.8 \pm 6.9$ K

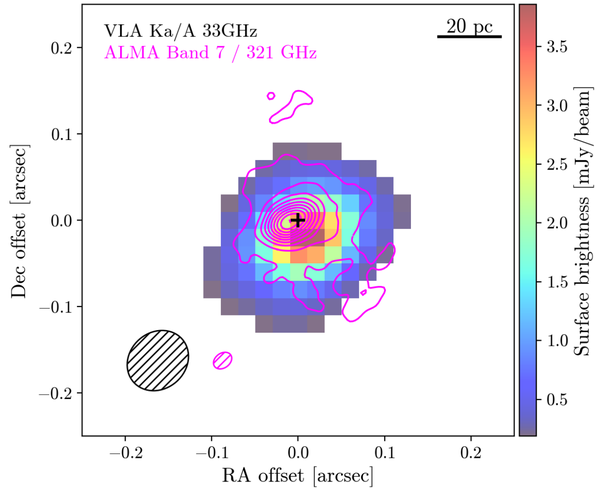
VLA

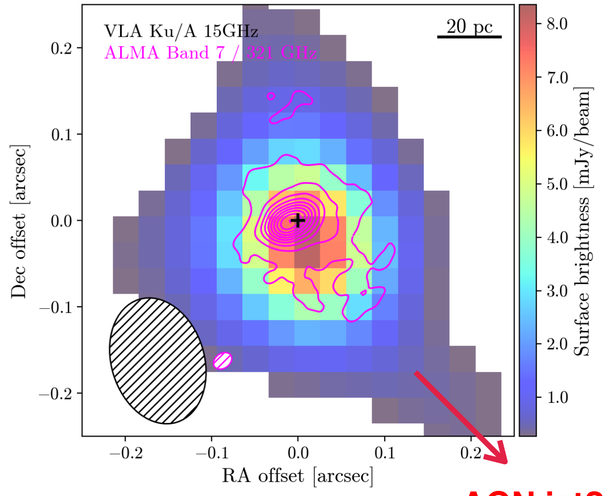




ALMA Band 7 / 321 GHz

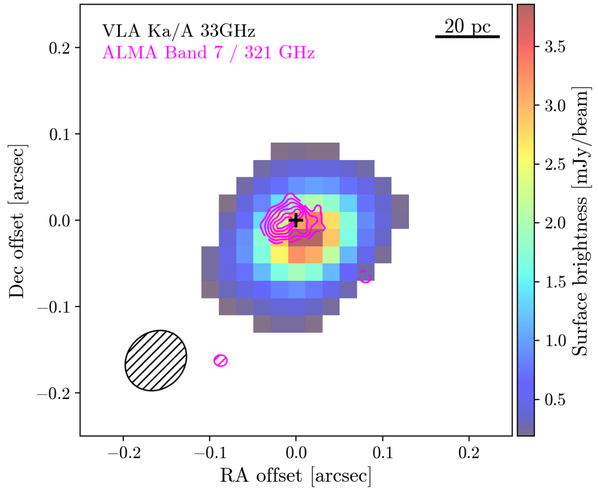
Natural

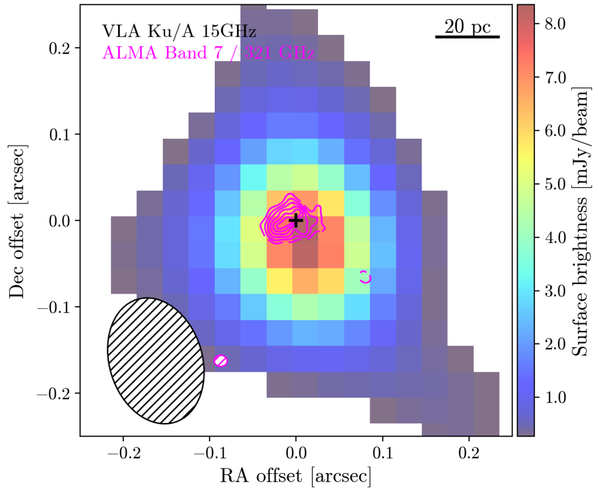




AGN jet?

Uniform





Moment maps: ^{13}CO

Preliminary results

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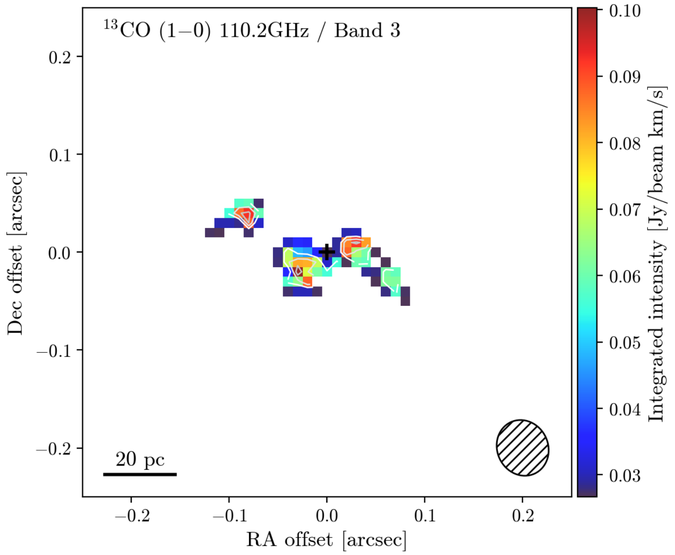
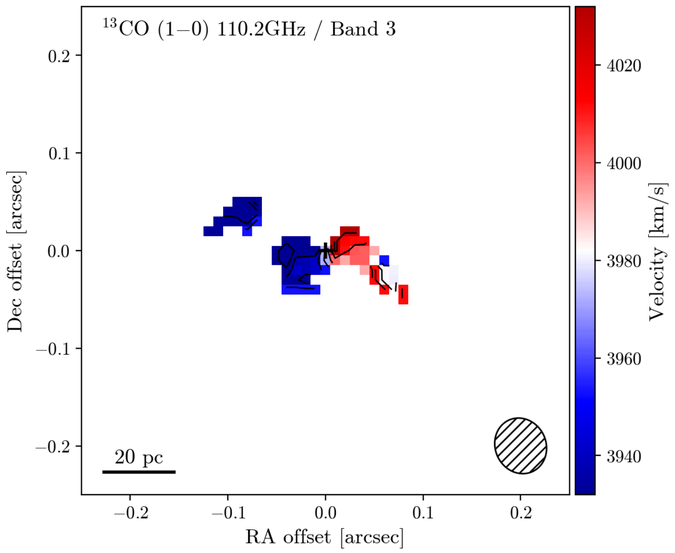
$S_{\nu,\mathrm{peak}} = 0.10 \pm 0.02\,\mathrm{Jy/beam \cdot km/s}$ FWHM $= 0.057\,\mathrm{arcsec} = 16.30\,\mathrm{pc}$

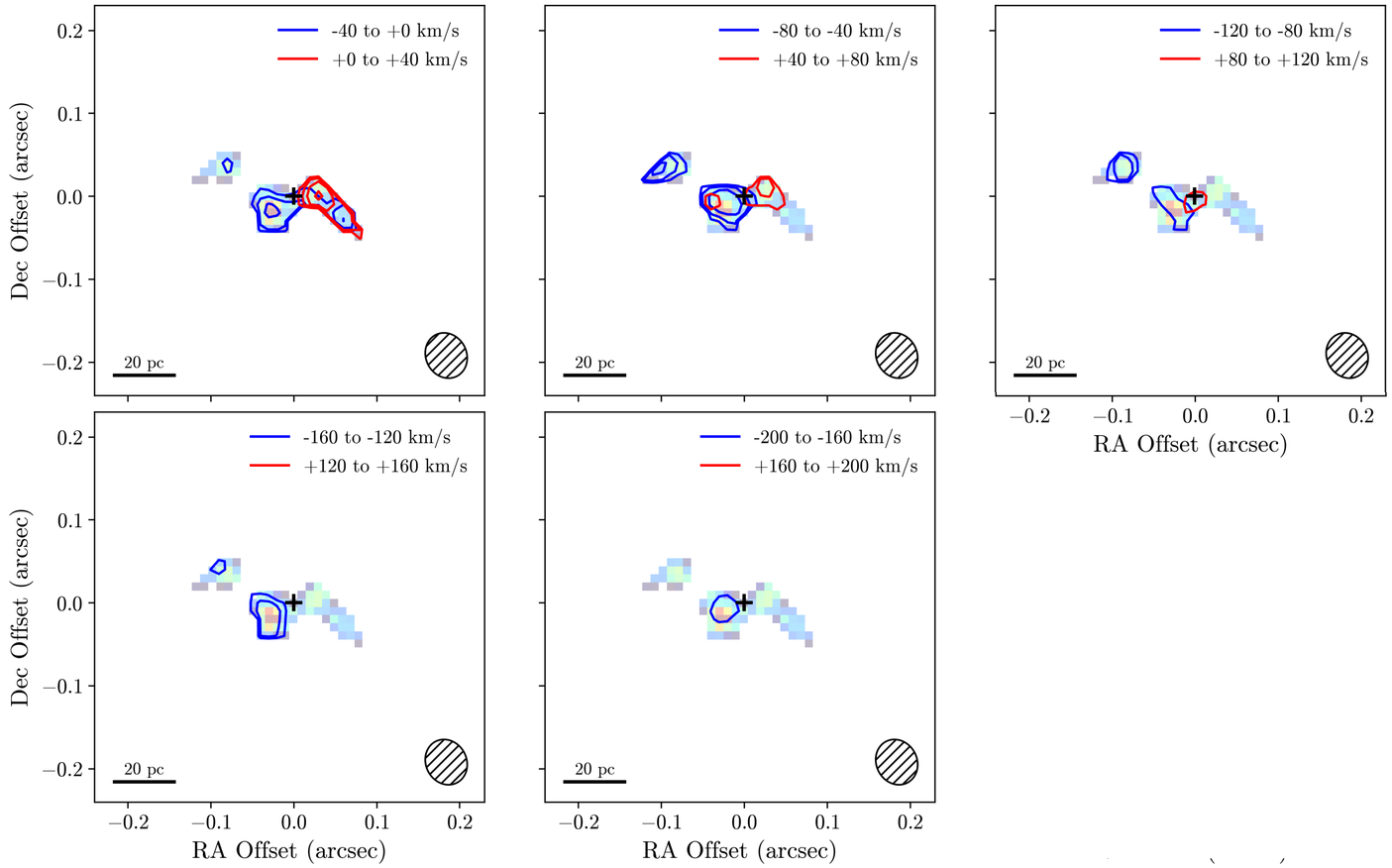
$S_{\nu,\mathrm{int}} = 0.11 \pm 0.02\,\mathrm{Jy \cdot km/s}$ $L'_{^{13}\mathrm{CO}} = 9.1 \cdot 10^5\,\mathrm{K\,km/s\,pc^2} = 40\,L_\odot$

Tracer of ‘total’ molecular gas





^{13}CO (1–0) 110.2GHz / Band 3 [$v_{syst} \sim 3987$ km/s] // Contours: 0.03 Jy/beam



Moment maps: HCN-vib

Preliminary results

Torbaniuk et al. 2026, in preparation

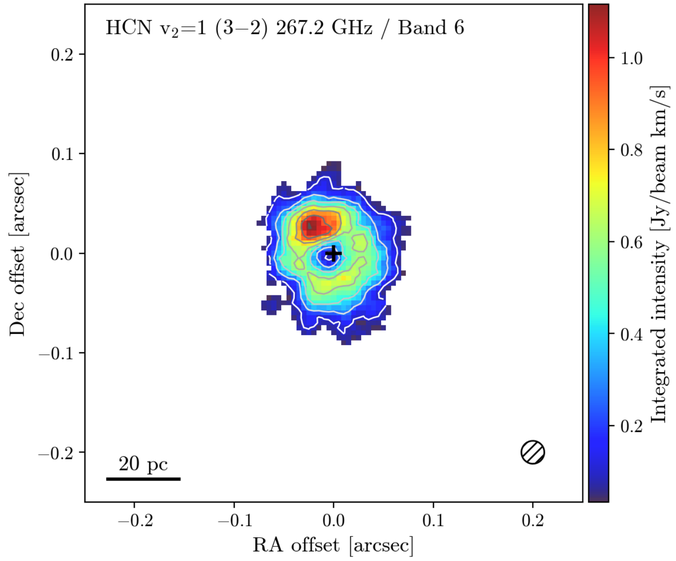
Tracer of very dense, not molecular gas

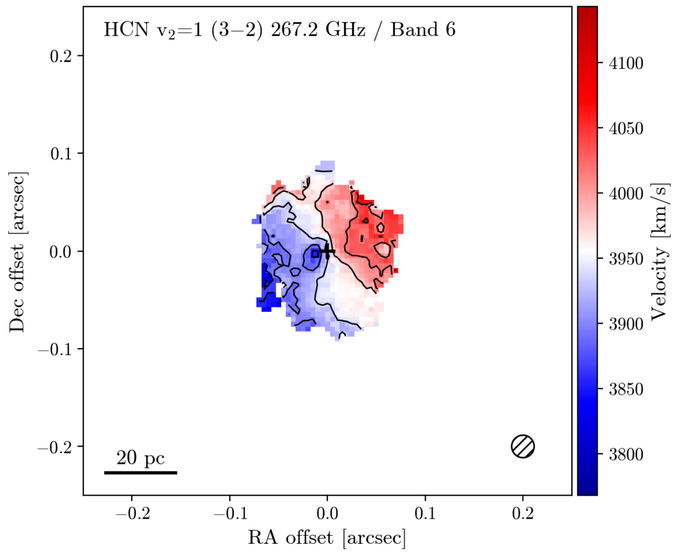
$S_{\nu,\mathrm{peak}} = 1.12 \pm 0.03\,\mathrm{Jy/beam \cdot km/s}$

$S_{\nu,\mathrm{int}} = 11.25 \pm 0.12\,\mathrm{Jy \cdot km/s}$

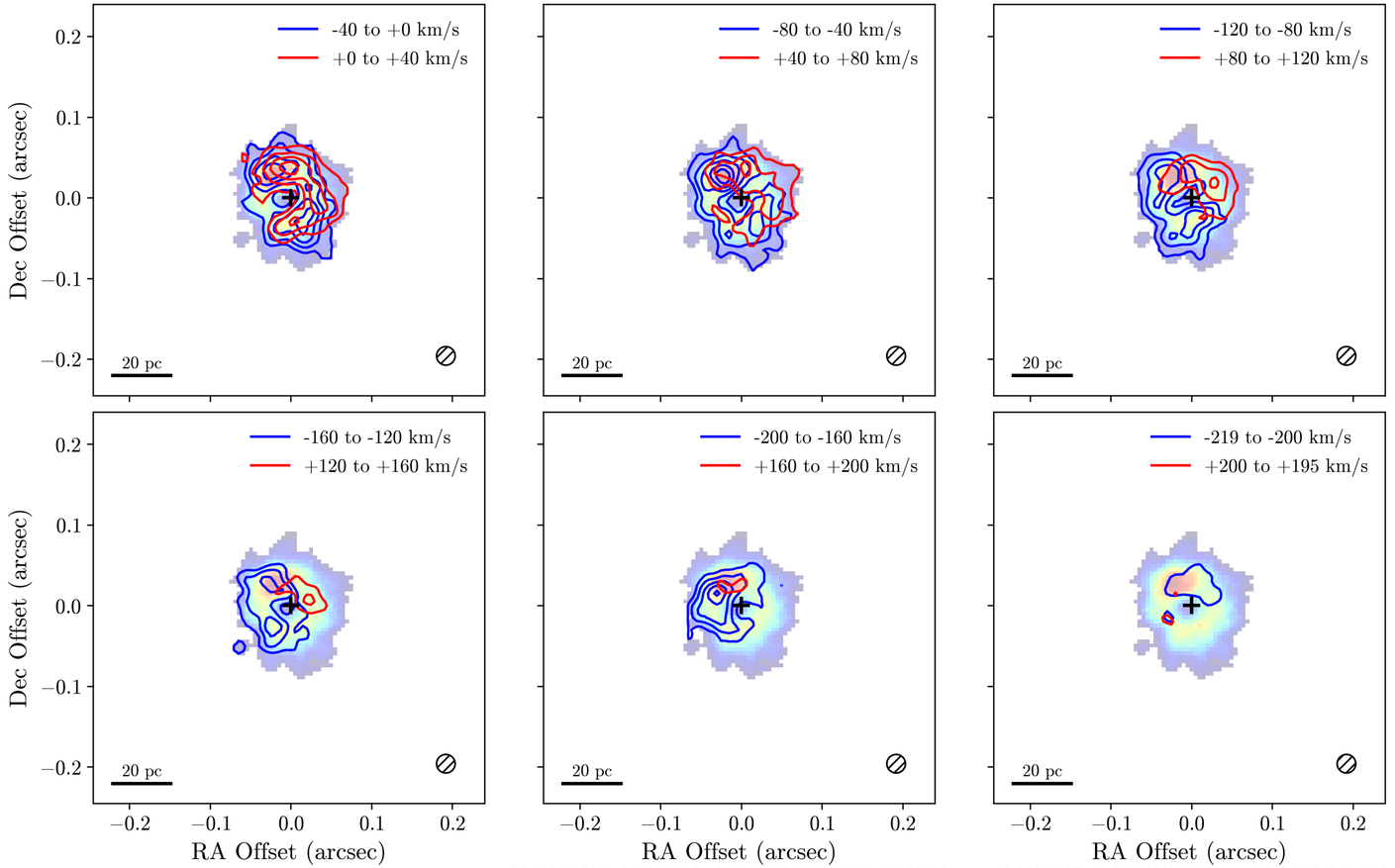
$L'_{\mathrm{HCN-vib}} = 1.7 \cdot 10^7\,\mathrm{K\,km/s\,pc^2} = 1.1 \cdot 10^4\,L_\odot$

$\mathrm{FWHM} = 0.095 \times 0.080\,\mathrm{arcsec} = 27.03 \times 22.85\,\mathrm{pc}$





HCN v_2=1 (3−2) 267.2 GHz / Band 6 [$v_{syst} \sim 3987$ km/s] // Contours: 0.05 Jy/beam



Moment maps: HCN

Preliminary results

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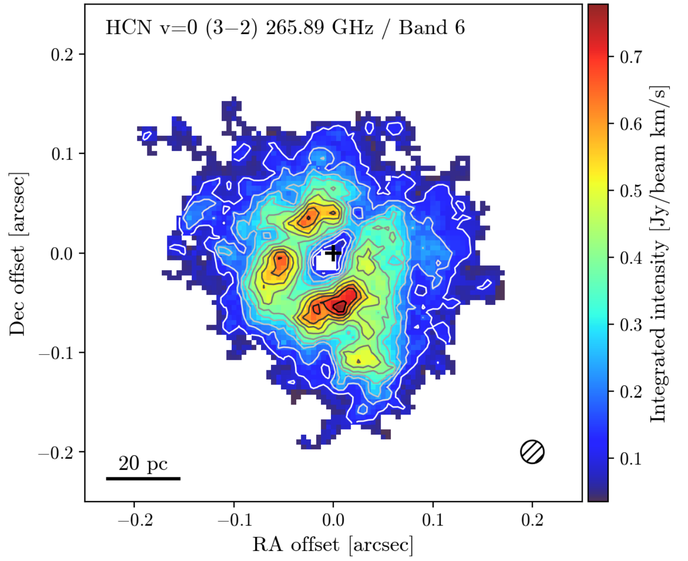
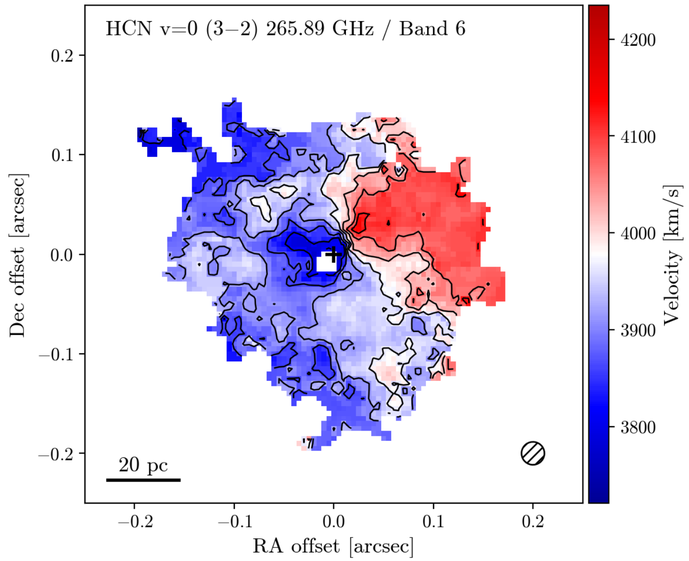
Tracer of dense molecular gas

$S_{\nu,\mathrm{peak}} = 0.78 \pm 0.02\,\mathrm{Jy/beam \cdot km/s}$

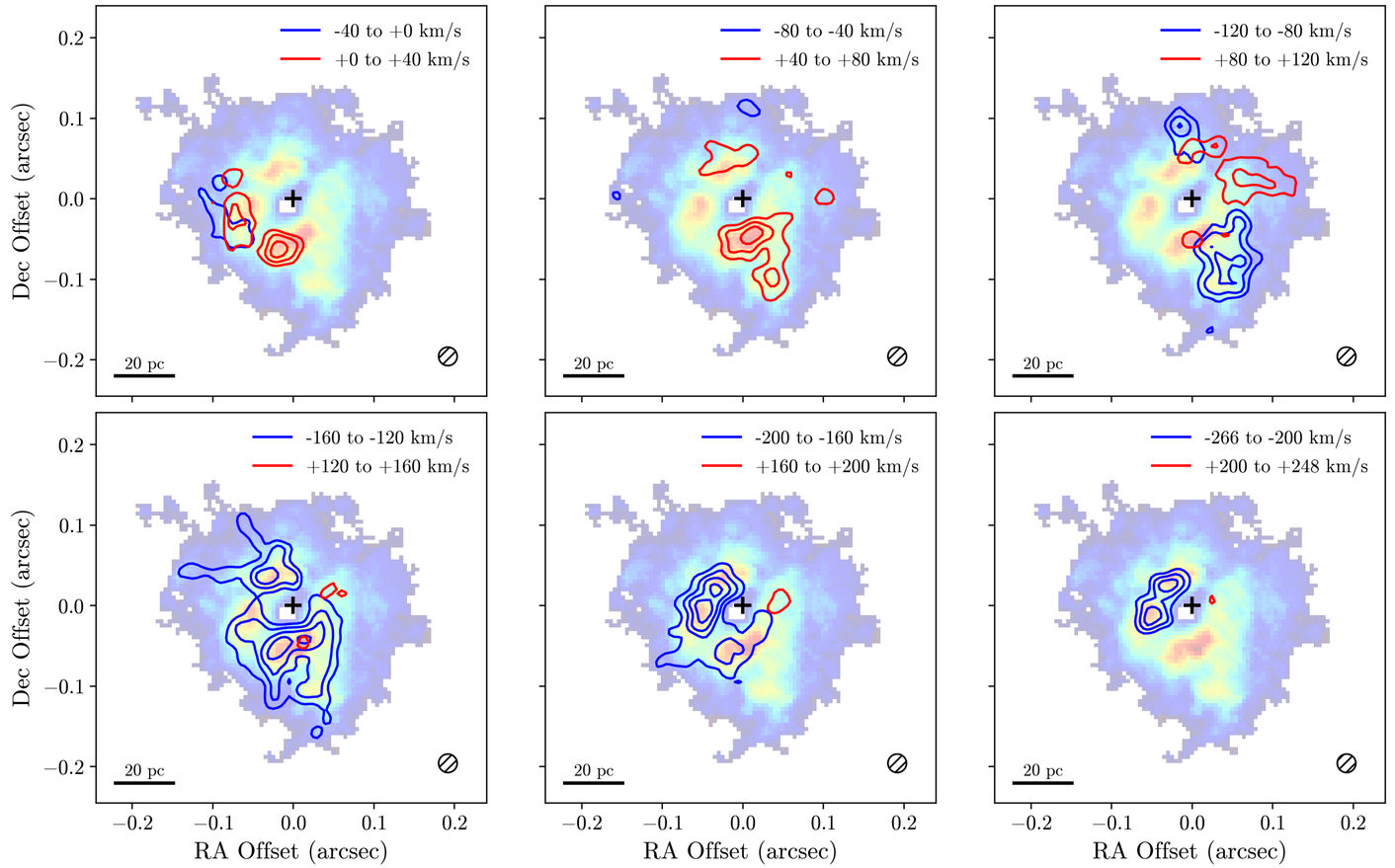
$S_{\nu,\mathrm{int}} = 27.46 \pm 0.10\,\mathrm{Jy \cdot km/s}$ $\quad L'_{\mathrm{HCN}} = 4.2 \cdot 10^7\,\mathrm{K\,km/s\,pc^2} = 2.5 \cdot 10^4\,L_\odot$

$\mathrm{FWHM} = 0.178 \times 0.139\,\mathrm{arcsec} = 50.97 \times 39.73\,\mathrm{pc}$





HCN v=0 (3–2) 265.89 GHz / Band 6 [$v_{syst} \sim 3987$ km/s] // Contours: 0.07 Jy/beam



Moment maps: HCO+

Preliminary results

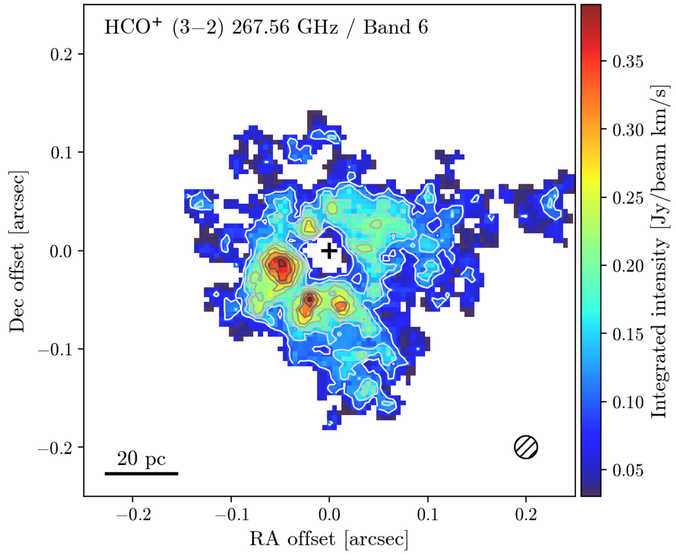
Torbaniuk et al. 2026, in preparation

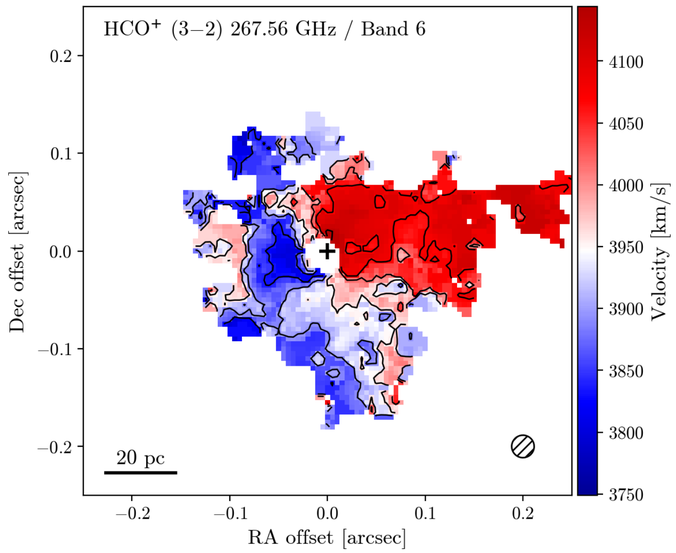
Tracer of dense molecular gas

$S_{\nu,\mathrm{peak}} = 0.39 \pm 0.07\,\mathrm{Jy/beam \cdot km/s}$

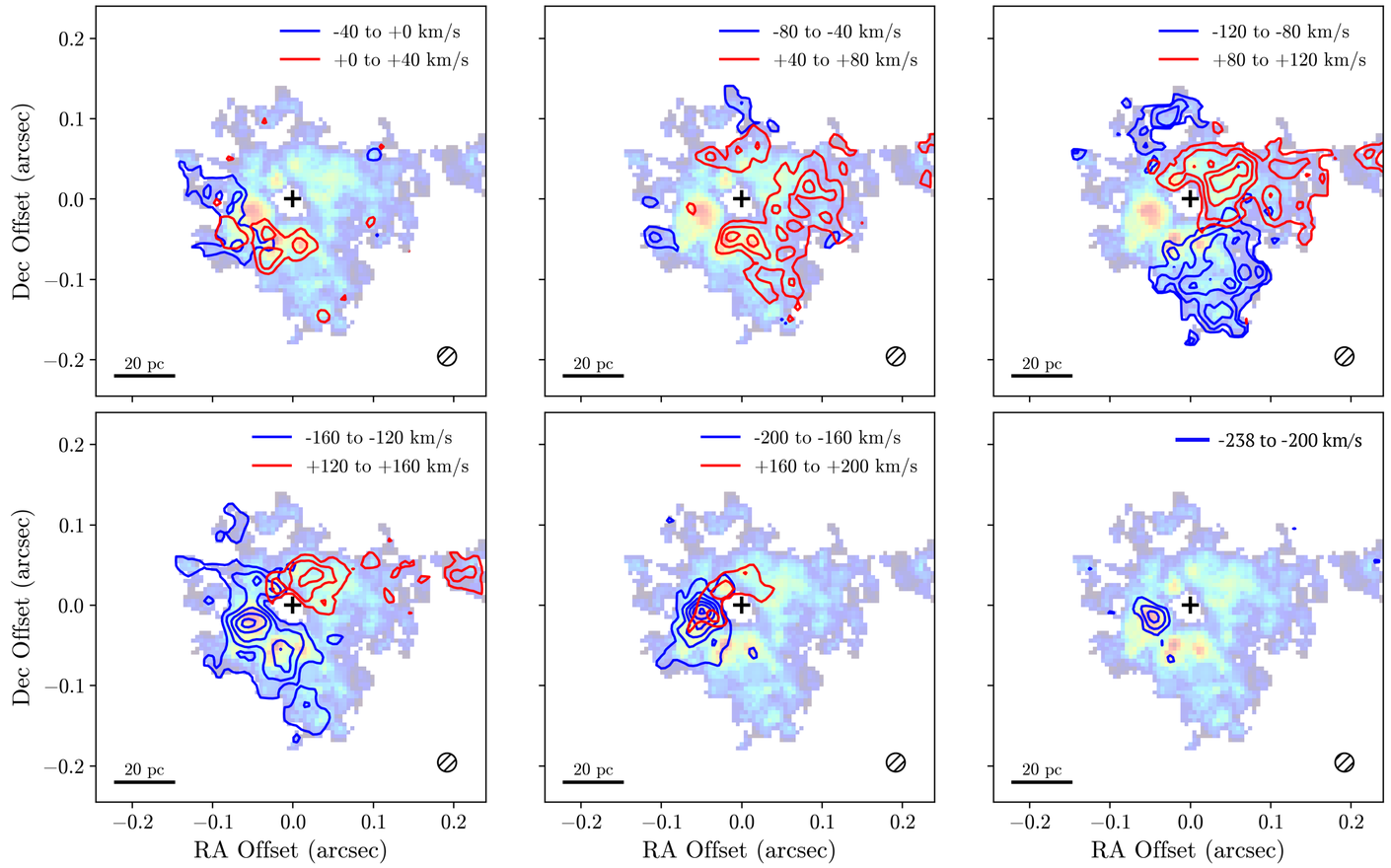
$S_{\nu,\mathrm{int}} = 12.08 \pm 0.12\,\mathrm{Jy \cdot km/s}$ $\quad L'_{\mathrm{HCO+}} = 1.8 \cdot 10^7\,\mathrm{K\,km/s\,pc^2} = 1.1 \cdot 10^4\,L_\odot$

$\mathrm{FWHM} = 0.169 \times 0.147\,\mathrm{arcsec} = 48.31 \times 42.16\,\mathrm{pc}$





HCO+ (3–2) 267.56 GHz / Band 6 [$v_{syst} \sim 3987$ km/s] // Contours: 0.04 Jy/beam



PV diagrams

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